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DEPARTMENT OF MARINE BIOLOGY
OF
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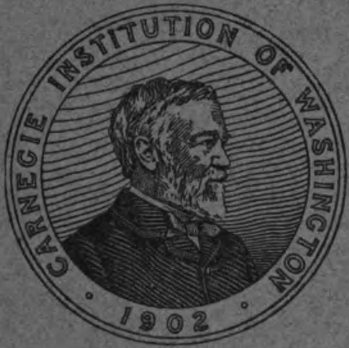
ALFRED G. MAYER, DIRECTOR

PAPERS FROM THE TORTUGAS LABORATORY
OF THE
CARNEGIE INSTITUTION OF WASHINGTON

VOLUME III



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I.

THE CONVERSE RELATION BETWEEN CILIARY AND NEURO-MUSCULAR MOVEMENTS.

BY ALFRED GOLDSBOROUGH MAYER,
Director of the Department of Marine Biology,
Carnegie Institution of Washington.

8 text figures.

THE CONVERSE RELATION BETWEEN CILIARY AND NEURO-MUSCULAR MOVEMENTS.

By Alfred Goldsborough Mayer.

This research was commenced at Tortugas, Florida, during the summer of 1909, and was continued in the Marine Biological Laboratory at Woods Hole, Massachusetts, and also at the New York Aquarium. I am greatly indebted to Prof. Charles R. Stockard of Cornell Medical College, Prof. Frank R. Lillie, Director of the Marine Biological Laboratory at Woods Hole, and Dr. Charles H. Townsend, Director of the New York Aquarium, for their kind aid in gathering and maintaining material alive for the research, and for granting to me the excellent facilities of the Woods Hole Laboratory and of the New York Aquarium. To Professors Carlton C. Curtis, of Columbia, and Roland Thaxter, of Harvard, I am also indebted for some highly appreciated advice upon the botanical side of the research.

Preliminary reports of the present research were published in the Biological Bulletin, Woods Hole, vol. 17, pp. 341, 342; in the Proceedings of the Society for Experimental Biology and Medicine, 1909, No. 7, pp. 19, 20: and in the Year Book of the Carnegie Institution of Washington for 1909, p. 152.

CONCLUSIONS NEW TO SCIENCE.

The effects of the several cations of the blood-salts, sodium, magnesium, calcium, ammonium, potassium, and hydrogen upon neuromuscular movements are in each case the exact opposite of their effects upon the ciliary movements of animals.

There is wide diversity in the reactions of various species of motile fungi and algæ to these ions, and the statement made in the preceding paragraph applies only to animals.

Ordinary ciliated epithelium such as that covering the external surface of Trematodes is not wholly under the control of the nervous or muscular system of the animal, and the cilia continue to beat even when the muscles underlying them contract.

The more highly specialized cilia, however, such as those of the meridional combs of Ctenophores, the lobes of veliger larvæ, the peristomial ring of trochophores, or the longitudinal band of Semper's actinian larva, cease to beat when the muscles underlying them contract, and resume their rhythmic movement only when the muscles relax. Thus an electrical stimulus which causes the muscles to contract stops the cilia, but if the muscles be anesthetized with magnesium so that they can not contract an electrical stimulus does not stop the cilia. The stopping of the cilia is therefore dependent upon the contraction of the muscles. It appears then that the stimulus which produces ciliary movement tends to cause muscular relaxation but is too weak to prevent muscular movement, but the stimulus which produces muscular contraction is of an opposite nature, and is more energetic than that required to maintain ciliary movement and completely overpowers it, stopping the cilia when the muscles contract. Considering all things which normally affect the animal, whatever stimulates the neuro-muscular system inhibits ciliary movement, and whatever stimulates cilia depresses neuro-muscular activity.

GENERAL CONCLUSIONS.

A research published in 1908 [1] leads me to believe that in Scyphomedusæ each pulsation is due to a stimulus produced by the constant setting free of ionic sodium in the marginal sense-clubs. Sodium oxalate appears to be constantly forming in the entoderm of the sense-club. This precipitates the calcium which constantly enters the sense-club from the surrounding sea-water, and thus insoluble crystals of CaC_2O_4 are formed while NaCl is set free. The Na ion is a powerful nervous stimulant, and being maintained thus in slight excess in the sense-clubs it acts as a constantly present minimal stimulus which produces periodic responses. It will be recalled that Romanes found that constantly present minimal electrical stimuli could cause periodically recurring pulsation in Scyphomedusæ.

Pulsation can not be maintained by the sense-organs unless calcium constantly enters them to form the crystals of calcium oxalate and to set free the ionic sodium, and all movement soon ceases in sea-water deprived of calcium.

In Cephalopods, Veligers, marine Annelids, Barnacles (*Lepas*), and Ctenophoræ, the sodium of the sea-water is a powerful neuro-muscular stimulant, whereas the magnesium, calcium, and potassium are inhibitors and counterbalance the stimulating effect of the sodium, giving a neutral or, more properly speaking, *balanced fluid*, thus permitting weak *internally engendered* stimuli to produce movements. This is very evident in the case of animals placed in distilled water, wherein they may move normally, although no direct stimulus to produce movement can come from the surrounding medium. Yet fresh-water animals react to sodium, magnesium, potassium, calcium, NH_4Cl, and CO_2 as do marine animals. Physiological conditions in vertebrates are often different from those in invertebrates, but it will be recalled that Martin, 1906,[2] concludes that the vertebrate heart is maintained in rhythmical activity by an inner stimulus due to the metabolic activity of the heart's own tissue, and its pulsation is not caused by an external stimulus due to the ions of the inorganic salts of the blood. Howell has also come to the conclusion that an inner and not an external stimulus causes the heart's activity, and Terry's[1] studies lead to the conjecture that the pulsation of *Gonionemus* may possibly be due to an oxidative process within the tissues.

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[1] Papers from the Tortugas Laboratory, vol. 1, pp. 115–131; Publication No. 102, Carnegie Institution of Washington.

[2] Martin, 1906, American Journal of Physiol., vol 16, pp. 191–220.

The calcium of sea-water combines with the sodium ion and assists the sodium to overcome the depressant effect of the magnesium. Calcium does not combine directly with magnesium, and in the *absence* of *sodium* it has no power to offset the depressant effect of magnesium. I first showed this in 1906, pp. 4, 46, and now present further experimental evidence to the same effect. It is also interesting to see that Joseph and Meltzer, 1910 (Proc. Soc. Experimental Biology and Medicine, vol. 7, p. 67), find that if the indirect irritability of the muscles of the frog be destroyed by perfusion with magnesium, the irritability can not be restored by calcium unless sodium be present.

It is remarkable that the effects of the ions sodium, magnesium, calcium, and potassium upon the ciliary movements of both marine and fresh-water animals are the *exact opposite* of their effects upon the neuro-muscular system. Thus for ciliary movement sodium is the most powerful inhibitor, while for the neuro-muscular system it is the most potent stimulant. Similarly, considering the ions magnesium, calcium, and potassium among themselves, magnesium is the most powerful stimulant for ciliary movement and the greatest depressant for neuro-muscular movements. Potassium in weak concentrations at first stimulates, but finally depresses the neuro-muscular activities, while it at first depresses and finally permits the movement of cilia. Calcium depresses neuro-muscular movement, but permits ciliary movement.

For neuro-muscular activities we find that the stimulating effect of Na is offset by the depressant action of Mg, K, and Ca; whereas in ciliary movements the depressant influence of Na is offset by the stimulation due to Mg, K, and Ca.

Thus marine invertebrates placed in 0.6 molecular NaCl have their muscular movements most highly accelerated, while their cilia cease to beat almost immediately after immersion in this solution. Also in 0.4 molecular $MgCl_2$ their neuro-muscular movements cease without initial stimulation soon after immersion, while their ciliary movements, although reduced in rate, are maintained for a long time. Ctenophores and ciliated Annelid larvæ illustrate these reactions very clearly.

R. S. Lillie, 1901–09, in an able series of papers in the American Journal of Physiology,[2] found that the muscular movements of marine animals were affected in a manner different from their ciliary movements by the ions Na, Ca, K, and Mg; but he did not observe that the action of these ions upon the neuro-muscular system is in each case the *exact opposite* of their effect upon cilia. I find, however, that this law holds not only for the above-mentioned ions of the blood-salts, but also for NH_4Cl, which at first stimulates but finally depresses the neuro-muscular movements of animals, while it at first checks and then permits of ciliary movement. Also weak concentrations of acids (hydrogen ion) are momentary stimulants but final depressants for the neuro-muscular system, while they are initial depressants for ciliary movement, but after a brief interval of cessation the movements of the cilia recover and become quite active.

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[1] Terry, 1909, American Journal Physiol., vol. 24, pp. 117–123.

[2] 1901, vol. 5, pp. 56–85; 1902, vol. 7, pp. 25–55; 1904, vol. 10, pp. 419–443; 1906, vol. 16, pp. 117–128; 1906, vol. 17, pp. 89–141; 1908, vol. 21, pp. 200–220, 1908, vol. 22, pp. 75–90; 1909, vol. 24, pp. 14–44; *Ibid.*, pp. 459–492.

It is probable that, in common with neuro-muscular movements, ciliary movement is not normally caused by stimuli originating from the outside, but is controlled by internal stimuli which in primitive cilia, such as those of ordinary epithelial surfaces, arise within each ciliated cell itself, and is only weakly under the control of the nervous or muscular system of the animal. Such ciliated cells may be separated one by one from the epithelium and each isolated cell still continues to lash its cilium in a normal manner. At best only a weak coördination exists between the constituent cells of such an epithelium, and impulses are only slowly transmitted by deep-seated cells lying under the cilia in the manner shown by Kraft, 1890, Archiv für gesammte Physiologie, Bd. 47, p. 196, or Gruetzner, 1882, Zur Physiologie des Flimmerepithels; Physiol. Studien, p. 1–32.

On the other hand, the more highly differentiated cilia, such as those of the combs of Ctenophores, which move in a coördinated rhythm, are certainly under the control of the nervous or muscular system of the animal. When this control is destroyed by placing the animal in magnesium chloride the cilia beat independently and incessantly and lose all coördination; thus reverting to the condition of the cilia of ordinary epithelia. It is therefore probable that for ciliary movement the combined stimulating effects of the magnesium, calcium, and potassium of the sea-water counterbalance the inhibiting effect of the sodium, for we find that in trochophores of marine annelids the cilia move with more than normal activity when the animals are placed in a solution lacking sodium but containing the proportions and amounts of magnesium, calcium, and potassium found in sea-water.

If, on the other hand, they be placed in a pure sodium solution, their cilia immediately decline and soon cease to beat and are so injured that recovery does not occur.

In experimenting upon the effects of the cations sodium, magnesium, calcium, and potassium upon unicellular motile fungi and algæ I find such great diversity in their reactions that one can not find any general law, this being in marked contrast to the uniform behavior of animals from the protozoa to the vertebrates. There is, however, an actively moving transparent *Spirillum* which lives in a culture of dead house-flies in fresh water containing algæ. This form reacts to the ions Na, Mg, Ca, and K as do the cilia of animals. It is therefore possible that the ciliary movements of animals were taken directly from their plant-like ancestors, while their muscular movements were developed only later and in a mode the exact converse of ciliary movement. This hypothesis must, however, be taken with the greatest reservation, and I present it only as a mere speculation calling for further study.

Hargitt, 1899 (Biological Bulletin, vol. 1, p. 42), succeeded in causing two individuals of *Gonionemus* to unite by their bell-rims, and whenever one of the individuals pulsated the other moved in coördination. The medusæ being joined rim to rim, it would seem, however, that if one pulsated the bell of the other must necessarily be mechanically drawn together even though the pulsation-stimulus might not be able to pass from one to the other. In order to obviate this possible ambiguity, two individuals of *Cassiopea xamachana* were joined together so that their subumbrella surfaces came in contact by a narrow isthmus, as shown in fig. 1. It was an easy matter to cause the medusæ to unite in this manner, but the union was usually of such a nature that no nervous intercommunication was established and the two animals although joined together continued to pulsate independently. In two instances, however, a nervous union was established in from 5 to 7 days after the operation, and then the individual which had the fastest rate of pulsation assumed control of the other, which always followed its every contraction. In both cases the small medusa, whose natural rate was the more rapid, controlled the larger one, and caused it to follow its rate; but if one pinched the bell-rim of the larger medusa its rate suddenly *increased* so that it became faster than the small medusa, and then it controlled the smaller until its excitement had subsided, when the smaller one regained its control. This shows that the complex formed of the two grafted individuals always pulsated at the rate of its faster member. Prof. Jacques Loeb has called attention to the fact that in a coördinated series of organs the whole series must beat at the rate of its fastest component, and in this connection he cites the book-gills of *Limulus*, for he finds that the whole series of gills moves at the rate of its fastest member. Long before this Romanes demonstrated that *Aurellia* pulsates at the rate of its fastest working sense-organ.

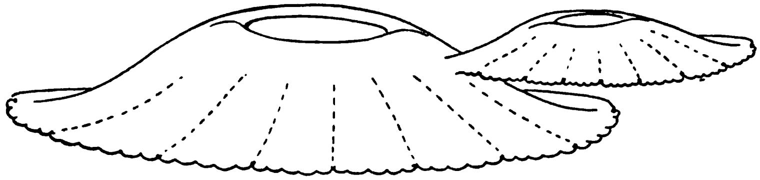

Fig. 1.—Two individuals of *Cassiopea xamachana* grafted one upon another.

I found that if the two medusæ of the complex were cut apart by severing the narrow isthmus of connecting tissue, the rate of each is lower than that of the two when beating together. Thus in one case the two medusæ joined and beating in unison had a rate of from 31 to 34 pulsations per minute, but when cut apart one of the medusæ had a rate of 26 to 29 and the other 18 to 25 per minute. It is evident, therefore, that the two medusæ together behaved, in so far as pulsation is concerned, as if they constituted a single individual, for Eimer and also Romanes long ago demonstrated that small pieces cut from a pulsating medusa beat slower than large ones.

A certain nervous *tonus* is imparted to the sense-organs if they be in nervous connection with a large area of subumbrella tissue. It is evident that this tonus is not of a trophic nature, for the lowering of rate occurs immediately when the medusæ are severed one from another, and the isthmus of connecting tissue was far too narrow to permit of any considerable interchange of circulatory or nutrient fluids between the two medusæ.

In experimenting with circuit-waves in ring-shaped strips of subumbrella tissue of *Cassiopea* or *Stomolophus* it is often desirable to be able to direct the course along which the wave shall travel.

This can be accomplished if a slight momentary pressure, such as the touch of a finger, be brought to bear upon the ring near the point of stimulation and opposite to the direction in which one desires the wave to travel. Thus in fig. 2 the star (*) marks the point at which the ring is to be stimulated, while the dotted area marks the pressed place, and the arrow shows the direction of the resulting wave which will continue to travel around and around the ring. That half of the initial wave which proceeds to the pressed place is so much dampened and reduced by the poorly conducting tissue of the pressed area that the wave in the opposite direction annuls it when they meet.

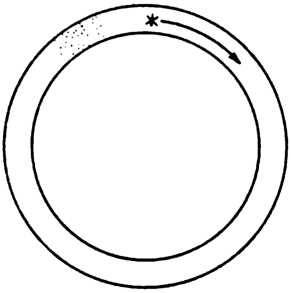

FIG. 2.—Method of determining direction of a wave of contraction.

DETAILS OF EXPERIMENTS.

PART I.

NEURO-MUSCULAR MOVEMENTS.

An extensive series of observations was carried out upon the effects of the cations sodium, magnesium, potassium, and calcium upon the neuro-muscular movements of *Lepas* and of Annelid worms at Tortugas. The Annelids experimented upon were several common species of Eunicidæ found in the crevices of coral rock, among them being the Atlantic palolo worm *Eunice fucata*. I also made use of several forms of *Nereis*.

The sea-water at Tortugas is well imitated for physiological purposes by a van't Hoff's solution consisting of $100NaCl + 7.8MgCl_2 + 3.8MgSO_4 + 2.2KCl + 2.5CaCl_2$, all of 0.625 molecular concentration. The Atlantic palolo *Eunice fucata* will live for over three weeks in this solution in an apparently normal condition. How much longer it might have survived I can not state, but the worms appeared to be normally active when the experiment was terminated; indeed, the worms and *Lepas* lived better in the artificial than in natural sea-water in aquaria under similar conditions in the laboratory. This I attribute to the purity of the Kahlbaum salts and of the distilled water used in making the artificial sea-water, and its consequent freedom from bacteria. It is remarkable that, contrary to Bethe's[1] experience in maintaining *Rhizostoma pulmo* alive in artificial sea-water at Naples, I found that the addition of a slight amount of $CaCO_3$ was not necessary and that it did not appear to improve the life-sustaining powers of the van't Hoff's solution. It produced, however, no injurious effect.

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[1] Bethe, 1908, Pflüger's Archiv für ges. Physiol., Bd. 124, pp. 541–577.

Figure 3 gives a graphic illustration of the effects of various solutions containing from one to three of the four constituent cations of van't Hoff's sea-water[1] on *Lepas* (left-hand column), *Cassiopea* (middle), and Annelid worms (right-hand column). The drawings of *Lepas* and of the Annelids are from careful sketches made from actual cases and are quite true to nature, but those of the Scyphomedusa *Cassiopea* are wholly diagrammatic, for the mouth-arms are not shown and the flattening of the bell in magnesium is much exaggerated in order to make it more apparent.

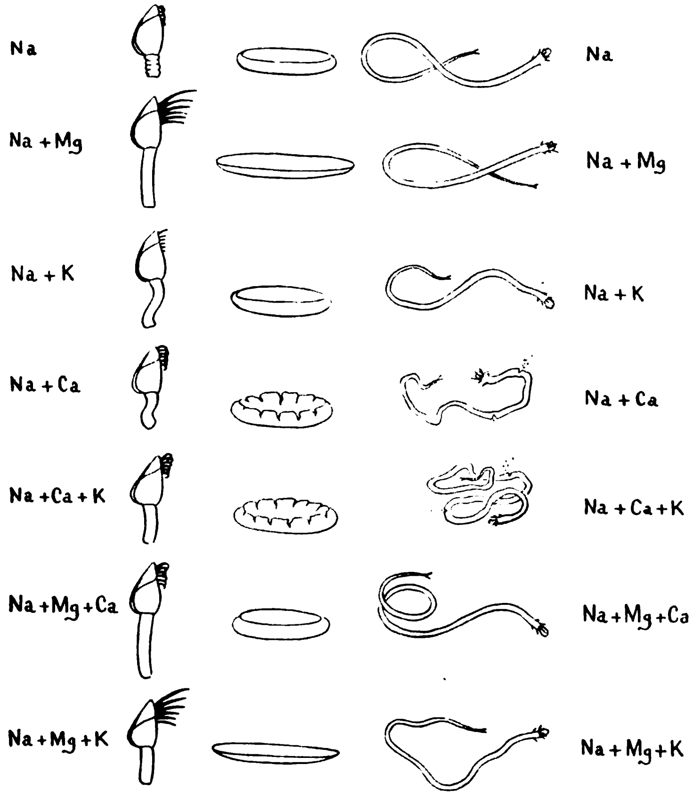

FIG. 3.

The figures show that muscular relaxation is produced in solutions containing magnesium, and tetanus in solutions containing calcium; also that calcium and magnesium counteract each the other in these respects when both are present in a solution containing sodium. Potassium, on the other hand, has but little power to alter the effects of calcium or magnesium. For example, in 0.625 molecular (100NaCl + 7.8$MgCl_2$ + 3.8$MgSO_4$) *Lepas* comes to rest without initial stimulation in about half an hour, with its pedicel abnormally extended and its branchial arms thrust straight outward without being recurved or crooked at the ends. *Cassiopea* soon flattens out, and the Eunicidæ and Nereidæ come to rest in relaxed, smoothly-flowing folds.

---

[1] The complete formula is 0.625 molecular (100NaCl + 7.8$MgCl_2$ + 3.8$MgSO_4$ + 2.2KCl + 2.5$CaCl_2$).

On the other hand, in solutions containing calcium but lacking magnesium we find that *Lepas* comes to rest with its branchial arms contracted and strongly recurved at their tips. *Cassiopea* tears its bell through muscular tetanus, and the annelid worms set themselves into rigid, distorted, sharply-twisted, "kinked" shapes, with spasmodic, local twitchings of the longitudinal muscles due to clonic tetanus, and often rents are torn through the cuticula, thus permitting the body-fluids to escape.

If, however, we have both magnesium and calcium in the solution they tend, in the presence of sodium, to offset one the other, the magnesium preventing tetanus and the calcium preventing complete relaxation. We see, however, that in the Na + Mg + Ca row the branchial arms of *Lepas* still tend to recurve at their ends as in calcium solutions, showing that the magnesium has not completely offset the calcium in this respect, although the pedicel is as fully relaxed as in magnesium solutions. It will be recalled that Meltzer and Auer, in a series of well-known and able papers have called prominent attention to the anesthetic (or asphyxiating[1]) influence of magnesium when introduced into the blood-system of vertebrates, and in 1908, in the American Journal of Physiology (vol. 21, p. 400), they announce that the effects of a lethal dose of magnesium upon a rabbit can be counteracted by a subsequent injection of calcium salt into its blood-system.

The drawings also show the strong stimulating effect of sodium, for in 0.625 molecular NaCl, *Lepas* comes to rest after abnormally active movements of its branchial arms, with its pedicel strongly contracted and usually with its shells shut and arms withdrawn; although in the specimen I have figured the arms are slightly projecting with their tips strongly recurved, this being the only solution save those containing calcium, which commonly causes a "crooking" of the tips of the arms. The medusa and the annelids move with abnormal rapidity in NaCl but come to rest without tetanus, although not in so completely relaxed a state as when in Na + Mg.

Thus the effect of ionic sodium, magnesium, potassium, and calcium is in each case of the same nature in all of these invertebrates. Sodium stimulates, magnesium depresses, potassium, after a momentary stimulation, depresses,[2] and calcium depresses and produces tetanus in each of these animals; as, indeed, they do also in their effect upon the ganglia that control the heart of ***Limulus***, according to Carlson, 1906 (Amer. Journal Physiol., vol. 16, pp. 386–395);[1] Bethe's[2] studies on the effects of these ions upon *Rhizostoma pulmo* also show that this medusa behaves as does *Cassiopea.*

---

[1] See Guthrie and Ryan, 1910, American Journ. Physiol., vol. 26, p. 329.

[2] In experimenting upon Annelids and *Cassiopea* I find that the initial stimulus caused by the addition of a slight concentration of potassium to the sea-water can be counteracted if we add together with the potassium about 5.5 times the amount of magnesium in a solution isotonic with the potassium. As this is about the ratio of potassium to magnesium in normal sea-water, it is probable that the primarily stimulating effect of the potassium is offset by the magnesium of the sea-water, and thus the potassium of the sea-water may be considered as a simple depressant.

This similarity of behavior suggests that the stimulus which produces rhythmical or other neuro-muscular movements in all of these forms is of one and the same nature in each and all of them. It appears that a slight excess of sodium maintained at the ganglionic centers causes the nervous stimulus which produces pulsation in the medusa *Cassiopea,*[3] but I am unable to state what may be the normal cause of movements in the other animals experimented upon in this research. In both *Cassiopea* and the Annelids, however, 0.1 per cent oxalic acid in sea-water quickly produces a permanent paralysis of the central nervous system, leaving the muscles still capable of contracting locally under the influence of stimuli, such as the touch of a crystal of postassium sulphate, although the contraction spreads only in a slow myogenic manner from the stimulated point.

Moreover, in both the medusæ and the worms, if the animals be in sea-water and a small amount of a solution of 4 parts of sodium oxalate in 1,000 parts of sea-water be allowed to diffuse locally upon them from a pipette, movements wholly natural in appearance arise from the stimulated area and spread over their bodies. These experiments do not prove that the cause of movement is due to a slight excess of sodium at the ganglionic centers in these invertebrates, but they *suggest* that this is possible. It will indeed be remembered that Parker and Metcalf, 1906 (American Journal of Physiol., vol. 17, pp. 55–74), found that the earth-worm reacts vigorously to 0.002 molecular CaCl, responding to the cation, and that it is more sensitive to sodium than to ammonium, lithium, or potassium.

Also Carlson finds that sodium chloride isotonic with sea-water gives a primary augmentation to the ganglionic rhythm of the *Limulus* heart, and that the specific influence of sodium, ammonium, potassium, and magnesium on the heart's activity is similar or the same in *Limulus* and in the vertebrates. In *Limulus* the heart muscle is stimulated by sodium and depressed by magnesium, potassium, and calcium, as in *Cassiopea.*

In an interesting paper Mathews, 1907 (American Journal Physiol., vol. 19, pp. 5–13), finds that $MgSO_4$ depresses the heart action of all vertebrates, decreasing both amplitude and rate, but this effect is offset by $CaCl_2$, as is also the case in invertebrates.

We may conclude that while we can not prove that ionic sodium produces the nervous stimulus which results in muscular activity in invertebrates, we may logically entertain the suspicion that this is the case. Hering[1] was the first to publish the fact that vertebrate skeletal muscle may develop rhythmical contractions in a solution of sodium chloride, and Mines[2] has conducted a thorough study of this reaction, obtaining graphic records of the movements of amphibian skeletal muscles; he finds that under certain conditions a 6 or 7 per cent solution of NaCl will give rise to pulsations of the muscle which are comparable in regularity of rhythm to those of lymph-hearts or even of the heart itself. These movements may, however, be stopped by calcium chloride, and are, indeed, probably due to the abstraction of calcium from the muscle by the sodium solution. Hence calcium tends to inhibit the movements. Mines finds also that potassium chloride at first increases the rhythmical movements, but afterwards stops them entirely. It is evident that the action of sodium, potassium, and calcium is similar upon skeletal muscle and on Scyphomedusæ, Annelids, *Lepas* arms, and the heart of *Limulus*. (See Carlson.)

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[1] Mines, 1908 (Journal Physiol., Cambridge, vol. 37, pp. 408–444), finds that sodium, calcium, and potassium act upon pulsating skeletal muscles of vertebrates as described above for *Limulus, Cassiopea, Lepas,* and Annelids.

[2] Bethe, 1908 and 1909, Pflüger's Archiv für ges. Physiol., Bd. 124, pp. 541–577; Bd. 127, pp. 219–273.

[3] Papers from the Tortugas Laboratory of the Carnegie Institution of Washington, vol. 1, pp. 115–131, 1908.

Indeed in all essential respects the Annelids behave as does the Scyphomedusa *Cassiopea* to ionic sodium, potassium, magnesium, calcium, ammonium (NH_4Cl), weak concentrations of acids (H), and ionic CO_3. For example in *Cassiopea* the pulsation stimulus is transmitted by the nerves and is independent of muscular contraction, and also in the Annelid *Eunice fucata* the mid-region of the worm may be rendered inert through immersion in molecular $MgSO_4$, and yet if the anterior end of the worm be stimulated in any manner the posterior end may respond at once while the middle region remains inert. Thus the nerve-chain of the middle region may still transmit the stimulus without causing the magnesiumized segments to respond to it by muscular movement. This middle region will, however, still be capable of transmitting slowly from segment to segment a wave of myogenic peristalsis in the manner demonstrated by Friedlaender[3] for the earthworm.

It is well known that neurogenic stimuli pass more vigorously from head to tail than from tail to head, and in killing worms if one wishes to avoid contraction one should cause the killing fluid to pass from tail to head.

Contractions are caused by 0.625 molecular NaCl in severed parts of Annelids and in *Lepas* from which the central nervous system has been removed, but I am not sure that such pieces can be said to contract in a wholly myogenic manner. Distilled water gives the same effect in Annelids, and indeed any marked change in osmotic pressure of the fluid surrounding them causes a vigorous series of contractions.

If any part of the length of a worm be immersed in an excess of calcium, clonic tetanus with a peculiar convulsive twitching of the longitudinal muscles appears in the part affected, but this twitching does not spread to other parts of the worm, which remain quiescent if in normal sea-water. In *Cassiopea* also the local tetanus caused by calcium does not spread to parts of the medusa not affected by the calcium. If we touch the calcium-affected part of the worm with a crystal of NaCl, while the part is twitching in tetanus, it responds by a vigorous contraction which travels immediately throughout the length of the worm. This leads one to conclude that the calcium tetanus is myogenic, not neurogenic.

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[1] Hering, 1879, Sitzungs. Wien. Akad., Bd. 89, Abth. 3, p. 1.
[2] Mines, 1908, Journal Physiol. Cambridge, vol. 37, pp. 408–444.
[3] Friedlaender, 1894, Pflüger's Archiv ges. Physiol., Bd. 58, pp. 168–206.

Calcium-tetanus, as is well known, can be counteracted by magnesium, but in order to stupefy marine animals without any trace of distortion, one should use a pure 0.4 molecular $MgCl_2$ or a molecular $MgSO_4$ solution, which are practically isotonic with the NaCl of sea-water and which produce a complete relaxation of the muscles without any considerable initial stimulation. In this respect they are more efficient and much quicker in action than a mere excess of magnesium in sea-water.

In solutions containing ionic sodium any calcium which may be present tends to counteract the depressant effects of magnesium; but if sodium be absent the calcium has no power to offset the inhibiting tendency of magnesium. It seems therefore that the calcium ion combines with the sodium and forms a compound which is capable of overcoming the inhibiting effects of the magnesium.

In order to demonstrate the inability of calcium to offset the inhibiting effect of magnesium in a solution lacking sodium, I cut ten *Cassiopea* medusæ into quadrants. One quadrant of each medusa was placed in $MgCl_2$, another in $MgCl_2 + CaCl_2$, another in $MgCl_2$ + KCl, and the fourth quadrant in $MgCl_2 + CaCl_2$ + KCl; the proportionate parts of the Mg, Ca, and K being those found in sea-water. The result is shown in the following table, wherein the medusæ are numbered from I to X and the number of pulsations given by each quadrant of each medusa before coming to final rest is shown in the vertical columns. It will be seen that adding Ca to solutions of Mg or of Mg + K does not overcome their depressant powers. The medusæ come to rest after a very few pulsations in Mg, or Mg + Ca, but the addition of potassium causes a characteristic initial stimulus which sustains movement for a longer time than it can endure in pure Mg or Mg + Ca. Weak concentrations of the potassium ion are always a primary stimulant for the neuromuscular system and an initial depressant for cilia, and the potassium does not combine with any of the other metallic ions to produce this effect, but is itself competent to produce it.

Table showing the number of pulsations given by ten Cassiopea xamachana medusæ.

[Each is cut into quadrants and each of the quadrants placed in one or the other of the 4 solutions shown below:—Medusæ numbered I to X.]

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	Sum.
130 c.c. $\frac{4}{10}$ *m* $MgCl_2$	0	2	1	1	4	9	0	3	2	1	23
100 c.c. $MgCl_2$ + 21 c.c. $\frac{5}{8}$ *m* $CaCl_2$	0	4	1	5	0	3	0	2	2	0	17
100 c.c. $MgCl_2$ + 19 c.c. $\frac{5}{8}$ *m* KCl	16	25	19	23	20	13	25	22	13	15	191
$MgCl_2 + CaCl_2$ + KCl	17	23	15	34	18	28	27	16	14	8	200

It may be of some interest to observe that the palolo worm, *Eunice fucata*, if in the dark, writhes vigorously when stimulated by the light of a match or an incandescent electric lamp. This reaction is not due to heat rays, for the worm gives no response to the more intense radiant heat from a large dark area of heated iron. It is, however, sensitive to light rays between the red and violet, and will respond to the light of a two-candle-power incandescent electric lamp, the rays of which have passed through a layer of carbon bisulphide 60 mm. in thickness, thus filtering out the ultra-violet.

As was demonstrated by Hesse,[1] in other Annelids, the anterior end is most sensitive, the posterior end next, and the middle of the worm least sensitive to stimuli.

Solutions which consist of sodium, potassium, and calcium chlorides are powerful initial stimulants, but finally produce depression of movement and muscular tetanus in invertebrates. This deleterious effect can, however, be overcome by adding magnesium to the solution, although this destroys its stimulating properties.

PART II.

CILIARY MOVEMENTS.

Studies were made of the effects of various ions upon the ciliary movements of fresh-water infusoria, vertebrate spermatozoa, Annelid larvæ, Veligers, Actinian larvæ, and Ctenophoræ. Among Annelid worms I paid special attention to the trochophore larvæ of the Atlantic palolo worm, *Eunice fucata*, and of *Spirobranchus tricornis* and *Pomatostegus* *stellatus*, all three of which may be obtained in abundance at Tortugas, Florida. The trochophores of both *Spirobranchus tricornis* and *Eunice fucata* rotate axially in the manner of a left-handed screw as they advance in a sinuous path through the water. The rotation is in each case due to the set of the cilia (see fig. 4). In stale sea-water or in magnesium

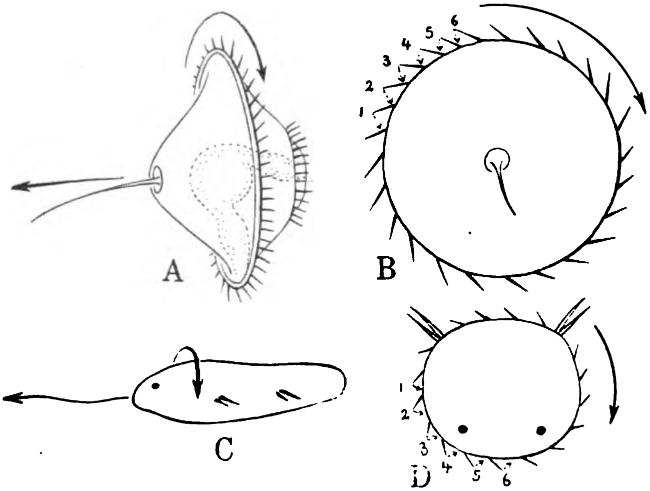

FIG. 4.—Above: *Spirobranchus* larvæ 48 hours old. Below: Palolo larvæ. A and C, side views. B and D, oral views. Arrows show direction of movement.

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[1] Hesse, 1896, Zeit. für wissen. Zool., Bd. 61, pp. 393–419.

solutions the larvæ are often observed to swim in circles, as shown in fig. 5. When young, the trochophores of *Eunice fucata* often turn over end for end as they advance through the water. When placed in a flat Petri dish in the diffuse light of the laboratory the larvæ of both these worms swim in all directions, at random, as is shown in fig. 6, which represents observed paths. When, however, larvæ enter the light meniscus on the side toward or away from the window they exhibit the Jennings-reaction, as is shown within the dotted areas in fig. 6. They are thus trapped in locations of optimum light-intensity, not directed toward the light along the path of the rays. This applies not only to the larvæ of the palolo but to *Spirobranchus* and *Pomatostegus*.

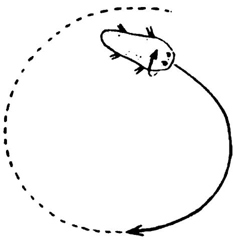

FIG. 5.—Palolo larva "circling" in a magnesium solution.

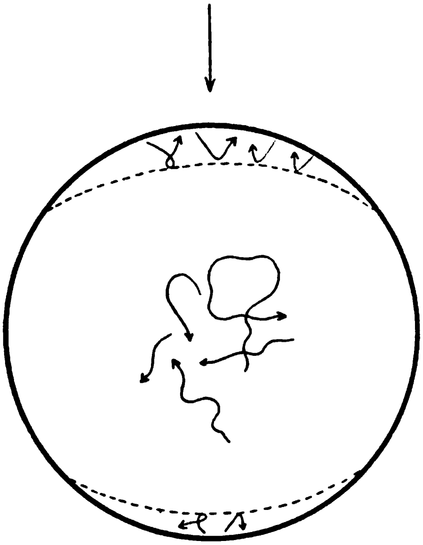

FIG. 6.—Paths of Palolo larvæ in a Petri dish.

It is remarkable that whatever the effects of the cations we are here considering may be upon the neuro-muscular system, their effect upon the movements of cilia are the exact opposite.

EFFECTS OF SODIUM.

A 0.6 molecular NaCl solution is a primary neuro-muscular stimulant, but its effect upon the ciliary movements of Infusoria, worm-larvæ, Veligers, Semper's Actinian larva, and Ctenophoræ is to derange and inhibit without initial stimulation, so that ciliary movement ceases usually in a few seconds, although in rare instances slight ciliary movement may continue in this solution for 20 minutes. In other cases, such as those observed by Prof. R. S. Lillie in *Arenicola* larvæ and in *Mytilus*, the cilia rapidly dissolve in NaCl. It is remarkable that while the ciliary movements are most seriously depressed in NaCl the neuro-muscular system is highly stimulated, and long after ciliary activity has ceased the muscles continue to contract and move actively.

Thus a solution of 5 grams of $Na_2C_2O_4$ in 1000 c.c. of sea-water is a stimulant for neuro-muscular movements, but it is a primary depressant for ciliary activity. A similar statement may be made of the effects of NaOH in sea-water.

After ciliary movement has ceased in 0.6 molecular sodium chloride solution, activity may be revived by placing the animals in isotonic magnesium solutions such as molecular $MgSO_4$ or 0.4 molecular $MgCl_2$; provided the cilia have not already dissolved in the sodium solution. When so revived by magnesium the cilia beat incessantly at a rapid rate while the muscles subside into quiescence.

EFFECTS OF MAGNESIUM.

Magnesium is the most powerful depressant among ions of blood-salts for the neuro-muscular system, but among these salts it is the most efficient single ion for maintaining ciliary movements. Its effects are thus the exact opposite of those of sodium. For example, the cilia of the trochophore larva of the palolo worm continue to beat for nearly an hour in pure 0.4 molecular $MgCl_2$, whereas such a solution causes muscular activity to cease in a few minutes. In 0.625 molecular ($100NaCl + 11.6MgCl_2$) the trochophores of the palolo and *Spirobranchus* soon begin to circle, as shown in fig. 5. At the end of about half an hour, however, they recover from this circling and move forward slowly, but in a normal manner. Some of them cease to move at the end of an hour, but a few continue to vibrate their cilia for from 3 to 7 hours, after which they die.

In the Ctenophore *Bolinopsis vitrea* the muscles are relaxed and the cilia are highly stimulated in magnesium, so that the animal darts with abnormal rapidity through the water, but the stroke of the cilia is *reversed* and the coördination destroyed, so that the creature moves *backward* (mouth forward) sometimes for more than 45 minutes.

Fresh-water infusoria, such as *Paramœcium*, soon cease to move their cilia in 0.166 molecular NaCl, but remain active a very much longer time in an isotonic solution of $MgCl_2$ or $MgSO_4$, although their rate is never as fast as the normal in these solutions.

Spermatozoa of terrestrial vertebrates cease to move almost instantly in NaCl, but will continue to move for more than an hour in $MgCl_2$. In the worm larvæ, Veligers, Actinians, and Ctenophoræ it is noticeable that the cilia continue to beat in magnesium long after muscular activity has ceased.

The addition of potassium or calcium to solutions composed of sodium and magnesium greatly prolongs their power to sustain ciliary movement. Thus in 0.625 molecular ($100NaCl + 11.6MgSO_4 + 2.2KCl$) cilia of the trochophores of the palolo and *Spirobranchus* cease at once to beat, but in a few seconds they recover and the larvæ swim for from 18 to 48 hours at a rate nearly if not quite normal, reacting normally to light. This behavior is remarkable in contrast with that of neuro-muscular movements in the same solution, for in this solution *Cassiopea* ceases to pulsate in about 6 minutes, Annelids cease to move in from 19 to 70 minutes, and the branchial arms of *Lepas* can not continue their rhythmical movement for more than 45 minutes.

Upon Ctenophoræ the above solution also causes a momentary cessation of ciliary movement followed by recovery, so that the cilia may continue to beat in a normal rate and manner for more than 9 hours. In some cases, however, the cilia, after having recovered their movement, *dissolve* and disappear in a few minutes—a most dramatic occurrence.

The body-movements of the Ctenophoræ cease in about half an hour in this solution. I am inclined to regard the sudden disappearance of the cilia in these Ctenophores as being possibly due to a nervous derangement, for I have seen it occur in *Cestum* in natural sea-water, the animal suddenly tearing itself into fragments and destroying its entire body without any apparent external cause.

It is evident that while potassium has but little ability to offset the inhibitory effect of magnesium upon neuro-muscular movements, it exerts a marked influence in sustaining ciliary movements in solutions containing magnesium.

A solution composed of sodium, magnesium, and calcium chlorides in the amounts and proportions of van't Hoff's solution[1] is also efficient in sustaining ciliary movement, for in this we find no preliminary checking of ciliary movement of the palolo trochophores, and the cilia continue to move for more than 48 hours, the rate continually *increasing* until it becomes fully that of the normal animal at the end of 24 hours, after which it declines. The *Spirobranchus* trochophores, however, behave somewhat differently, for their bodies degenerate into mere sacs (fig. 7), and finally, after from 18 to 24 hours, the cilia themselves are gradually absorbed, although still beating until they disappear. In fig. 7, the upper part of the figure shows the normal trochophore of *Spirobranchus;* the lower shows the effect of 18 hours' immersion in a solution containing amounts and proportions of sodium, magnesium, and calcium found in sea-water.

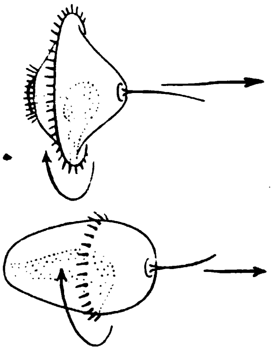

Fig. 7.

Those solutions which are most efficient in stimulating ciliary movement are the strongest depressants of neuro-muscular activity. For example, neuro-muscular movements cease almost immediately in 0.625 molecular $MgCl_2$ or 0.625 molecular ($12MgCl_2 + 2.5CaCl_2$) or in 0.625 molecular ($12MgCl_2 + 2.5CaCl_2 + 2.2KCl$). In the last-named solution the cilia exhibit a momentary pause or a lowering of rate for a few seconds after being placed in the solution, this effect being seen in all solutions containing potassium. After this, however, they quickly recover and beat at an abnormally rapid rate but without coördination, each cilium beating independently of its neighbors. This loss of coördination is well illustrated in Veligers, Ctenophores, Trochophores, or Semper's Actinian larva, and is due to the fact that the neuro-muscular system is paralyzed by the magnesium and loses control of the cilia, which thus revert to the primitive condition in which they are not appreciably influenced by the neuro-muscular system but each cilium is controlled chiefly by its own cell.

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[1] 0.625 molecular ($100NaCl + 7.8MgCl_2 + 3.8MgSO_4 + 2.2KCl + 2.5CaCl_2$).

After cilia have ceased to beat in a magnesium solution they may be restored to temporary activity by 0.625 molecular NaCl. In this case ciliary movement is regained in the sodium chloride before the muscles revive their activity, and the cilia cease to beat long before the muscles cease to contract. The cilia cease to beat, or are dissolved, in from 4 to 8 minutes after being immersed in the sodium chloride, while the muscles may continue to contract for half an hour or more. Often individual ciliated cells are cast off from the epithelium and set free with their cilia lashing vigorously, and if these freed cells be restored to sea-water they continue to beat actively for hours in a normal manner, thus showing that primitive ciliated cells are practically independent of the neuro-muscular system of the animal, and each cell contains within itself its own means of maintaining its movement.

EFFECTS OF POTASSIUM.

It will be recollected that potassium in weak concentration is a powerful but only momentary stimulant for neuro-muscular movements, this initial activity being followed quickly by pronounced depression and toxic effects. Upon cilia, however, its effects are the exact opposite. Thus the movements of the cilia of the worm-trochophores, Veligers, and Ctenophores are momentarily checked by a solution containing the amounts and proportions of potassium and sodium found in sea-water,[1] but after a few seconds of arrested movement recovery takes place and they beat slowly for about half an hour in the case of the Veligers or worm larvæ, and for about 4 hours in that of the Ctenophores.

The muscular movements in all of these forms are at first highly stimulated by this solution, but depression follows, so that the muscles cease to move long before ciliary activity dies out.

The movements of the cilia of the fresh-water *Paramœcium* are at first checked by a weak concentration of potassium chloride or sulphate, so that they cease to beat, or the animal reverses or spins in a circle. Soon, however, recovery takes place and the *Paramœcium* swims slowly but normally forward. Jennings[2] first observed that *Paramœcia* placed in a 1 per cent solution of potassium iodide at first swim backward, then spin around on the short axis of the body for half an hour or more, and finally recover and swim forward.

Parker[3] finds that 2.5KCl in 100 sea-water reverses the stroke of the cilia of *Metridium*, and the same effect is produced by meat-juice, but in this case probably not by the contained potassium, but by the creatine in the meat.

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[1] 0.625 *molecular* (100NaCl + 2.2KCl).
[2] Jennings, 1899, Amer. Jour. of Physiol., vol. 2, p. 319.
[3] Parker, G. H., 1905, Amer. Jour. Physiol., vol. 14, p. 5.

R. S. Lillie[1] found that pure solutions of potassium of 0.5 molecular concentration are capable of long maintaining the activity of the cilia of *Arenicola* larvæ and *Mytilus*, and it is of interest to observe that such strong concentrations of the potassium ion immediately depress neuro-muscular movements without primary stimulation, thus acting upon the neuro-muscular system in a manner the exact reverse of their effect upon cilia.

EFFECTS OF CALCIUM.

Strong concentrations of calcium such as 0.5 molecular $CaCl_2$ quickly check ciliary movement in worm larvæ, Veligers, and Ctenophores without destroying the cilia. In *Mytilus*, however, according to Lillie (1906, p. 130), ciliary movement may last for several hours.

In weak concentrations, however, or if combined with NaCl, ciliary activity continues much longer in calcium solutions than do the neuro-muscular movements. We may conclude that calcium in combination with sodium is a stimulant for the movement of cilia, for it prolongs the duration and increases the rate of movement over and above that caused by NaCl alone.

The larvæ of the palolo worm will swim slowly without an initial stop for about half an hour in 0.625 molecular ($100NaCl + 3CaCl_2$), while *Spirobranchus* larvæ will beat from 45 to 90 minutes, and Ctenophore cilia will vibrate with abnormal rapidity for from 6 to 30 minutes in this solution, the coördination being in many cases destroyed, so that each comb beats independently of its neighbors and the animal is unable to progress despite the fact that its cilia are abnormally active. In this connection it is interesting to observe that Lillie[2] finds that mechanical stimulation arrests the automatic activity of the swimming-plates of Ctenophores, but that this does not occur in the absence of calcium, and the effect decreases as the calcium is decreased.

Carlson, 1906,[3] concludes that calcium depresses both the ganglia and the muscles of the heart of *Limulus* without primary stimulation; and my studies of *Cassiopea* led me in 1908[4] to a similar conclusion in respect to this animal. Authorities differ in respect to the rôle played by calcium in the pulsation of the vertebrate heart. We must remember that calcium combines with sodium, forming a compound which offsets the inhibitory effects of *magnesium*, and it appears to me that the so-called stimulating effect of calcium is due to this secondary action, for if sodium be absent calcium has no power to overcome the depressant action of magnesium. In the case of *Cassiopea*, calcium augments the rate of pulsation only if added to solutions containing sodium and magnesium, and it is evident that this effect is due to its combining with sodium, thus forming a compound which counteracts the depressant effects of magnesium, not to any direct stimulating action of its own.

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[1] Lillie, R. S., 1902, Amer. Jour. of Physiol., vol. 7, pp. 46, 52; also, *Ibid.*, 1906, vol. 17, p. 93.

[2] Lillie, R. S., 1908, Amer. Jour. Physiol., vol. 21, pp. 200–220.

[3] Carlson, 1906, Amer. Jour. Physiol., vol. 16, pp. 390, 394.

[4] Papers from the Tortugas Laboratory of the Carnegie Institution of Washington, vol. 1, 1908, pp. 115–131.

For example, when calcium is added to a pure NaCl solution, the rate of pulsation in *Cassiopea*, *Lepas* (branchial arms), and in pulsating skeletal muscle is *lowered*, not increased, as we would expect were calcium a stimulant.[1] If, however, we add calcium to a solution containing *both* NaCl and magnesium, the rate is increased. I am led to conclude that in all of these animals, as in *Limulus*, calcium is a depressant. A more complete discussion of this question will be found in my paper of 1908.

In combination with sodium, however, calcium appears to be a stimulant for ciliary movement, for it greatly prolongs the duration of the activity of cilia if added to a pure sodium solution, and causes them to beat faster than in NaCl.

EFFECTS OF CARBON DIOXIDE.

In strong concentration carbon dioxide in sea-water quickly checks ciliary movement without initial stimulation. A weak concentration of the CO_3 ion in sea-water, however, at first stops all ciliary movement in trochophore larvæ, but after an interval of from 1 to 3 minutes the cilia begin to recover normal activity. This effect is not due to the escape of CO_2 from the water, for if we place a lot of larvæ in the solution and after they have regained their ciliary movements introduce a second lot of larvæ, these newly introduced animals at once lose their ciliary activity, but afterwards recover. This reaction occurs in sea-water at 82° F. which has been charged with CO_2 in a "sparklet" bottle and then exposed to the air for 8 hours in a shallow Petri dish.

EFFECTS OF WEAK CONCENTRATIONS OF ACIDS, AMMONIUM, ETC.

Weak concentrations of lactic or uric acid (H ion) are primary depressants for ciliary action but are initial neuro-muscular stimulants, although this momentary stimulation is quickly followed by depression.

The ammonium ion (0.625 molecular NH_4Cl) at once stops ciliary movement in *Spirobranchus* trochophores, but after being in the solution for about 3 minutes they begin to beat and recover fairly well, moving for about half an hour, but never with fully normal activity. It is interesting to observe that the muscular system of these larvæ is instantly stimulated as soon as they are introduced into the 0.625 molecular NH_4Cl, but depression soon follows; the effect of the solution upon the neuro-muscular system thus being the exact converse of its effect upon the cilia. NH_4Cl is also a powerful primary stimulant for the neuro-muscular system of *Cassiopea* or adult worms, but depression quickly follows.

A few crystals of urea, CH_4N_2O, added to sea-water cause an active initial stimulation of neuro-muscular movement followed by depression. The cilia, on the other hand, are stopped at first, but soon recover and beat at a rapid rate.

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[1] Bancroft, 1909, Journal Physiol., Cambridge, vol. 39, pp. 1–24, concludes in agreement with Loeb that stimulation must be associated with a decrease in concentration of calcium within skeletal muscles.

In a 0.625 molecular lithium chloride solution the cilia of *Spirobranchus* cease instantly, but do not dissolve, whereas they both cease at once and dissolve in a molecular dextrose solution in water.

SUMMARY.

Among the cations of sea-water sodium is the most potent inhibitor of ciliary activity and the most powerful neuro-muscular stimulant.

On the other hand, magnesium is the most potent in maintaining ciliary movement and the most powerful inhibitor of neuro-muscular movements.

Potassium in weak concentration is a primary depressant for cilia, but afterwards ciliary action recovers in its presence. For neuro-muscular movements, however, it is at first a stimulant and finally a depressant.

Calcium is a weak stimulant for ciliary movement, but a depressant for neuro-muscular activity.

Ammonium at first stops and finally permits the recovery of ciliary movement, but it at first stimulates and afterwards inhibits neuro-muscular movements.

Weak acids (H ion) at first depress and afterwards permit recovery of ciliary movement, but they at first stimulate and afterwards depress neuro-muscular movement.

In each case the effect of the solution is exerted through its cation, and among these cations whatever stimulates cilia depresses muscular activity and whatever inhibits muscular movement stimulates cilia. In nature the more highly specialized cilia, which are under the control of the neuro-muscular system, stop whenever the muscles contract, and beat only when the muscles are relaxed. This is well illustrated in the combs of Ctenophores, the cilia of the lobes of Veligers, or the ciliated bands of Trochophores, and Semper's larva.

At times the trochophore larva of *Spirobranchus* does not contract as a whole, but only a small sector of muscles underlying the peristomial ring of cilia contracts. In this case the cilia overlying the contracted sector immediately stop but the impulse which produces the "wheel movement" of the ring of cilia passes over the inert cilia without affecting them, so that the cilia of the uncontracted parts of the ring maintain their normal movement. This accords with Parker's[1] observation that cooling a part of the length of a row of ciliated plates in Ctenophores stops the combs over the cooled area, but does not inhibit the transmission of the wave impulse across this area. Kraft obtained similar results in his experiments upon the ciliated epithelium of vertebrates.[2]

We may present the results of this paper in a graphic manner if we represent a stimulus by a + sign and an inhibition of movement by a − sign. Successive effects may be represented by a succession of signs; thus, − + means a depression followed by recovery of movement and + − an initial stimulus followed by depression. Bearing this preamble in mind, the following table will illustrate the effects of the various cations:

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[1] Parker, G. H., 1905, Journal Experimental Zool., vol. 2, p. 417.

[2] Kraft, H., 1899, Pflüger's Archiv für ges. Physiol., Bd. 47, pp. 196–235.

Cation.	Effect on neuro-muscular movement.	Effect on movement of cilia of animals.
Sodium	+	−
Magnesium	−	+
Potassium	+ −	− +
Calcium	−	+
Ammonium	+ −	− +
Hydrogen	+ −	− +
Lithium	+	−

I am unable to interpret the meaning of this law of the converse effects of cations of blood-salts upon ciliary and upon the neuro-muscular movements of animals, yet any adequate explanation of the phenomena of animal movement must offer an explanation of this relation. Indeed the discovery of this converse relation makes very apparent the incompleteness of all existing explanations of the cause of animal movements.

The electrical stimulation obtained from an induction coil is peculiar in that it excites both the muscles and the cilia. Its effect is to cause the muscles to contract and this contraction stops the cilia in Ctenophores or Veligers, but if the muscles be paralyzed in magnesium so that they can not contract, or if the cilia be not underlaid by muscles, as in the auricles of *Bolinopsis vitrea*, they are excited when the electrical current passes through them. This leads one to suspect that, whereas a negative variation accompanies neuro-muscular contraction, a positive variation may accompany ciliary excitation, but this hypothesis I have not yet been able to test experimentally.

EFFECTS OF IONS UPON MOTILE PLANT-SPORES.

It is commonly supposed that ciliary movement is of a very primitive nature, and it naturally occurs to one that the ciliary movements of animals may be a heritage from their more or less plant-like ancestors. If this be true we would expect the motile spores of the lower plants to react to electrolytes as do the cilia of animals. I find, however, that there is wide diversity in the behavior of various motile plant-spores under the influence of ions, this being in marked contrast to the uniform reaction of animals, wherein one finds only differences of degree in the behavior of the cilia in forms so diverse as protozoa or spermatozoa, worm larvæ, ciliated epithelia of Molluscs, and the combs of Ctenophores. There is, however, a *Spirillum* which lives in a culture of dead house-flies in fresh water which reacts to ions somewhat as do the cilia of animals. This *Spirillum* is elongate, helically coiled, and of uniform transparency (fig. 8 A), and it thrives in the water containing

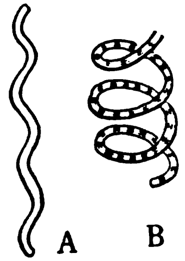

FIG. 8.—Two sorts of *Spirillum* living in a culture of dead flies in fresh water.

dead flies, provided green algæ, such as *Spirogyra*, be in the aquarium in which it lives. It is very active, darting rapidly through the water.

In 0.625 molecular sodium chloride it stops instantly, but in weak concentrations of sodium it may move for half an hour or more without initial stimulation and with gradual loss of movement.

In 0.375 molecular magnesium sulphate it continues to move slowly for about 90 minutes, gradually coming to rest.

In solutions of about 0.066 molecular potassium chloride we sometimes observe that the initial effect is to check or stop all movement, but after an interval of 2 or 3 minutes partial recovery takes place and the spirillum moves slowly forward in a normal manner. A slightly stronger concentration of potassium, however, checks movement without permitting recovery.

In 0.166 molecular calcium chloride it moves with normal activity for from 15 to 30 minutes and then suddenly ceases to move.

These reactions, it will be observed, are in each case identical in nature with those of animal cilia. In no other case, however, have I been able to find a plant-spore which reacts as do the cilia of animals. For example, another form of *Spirillum* living in this same dead-fly culture in fresh water will continue to swim for somewhat more than 3 hours in 0.625 molecular sodium chloride, being even abnormally active for the first few minutes in this solution. This spirillum is closely coiled and exhibits irregularly-spaced nodes of milky or ground-glass-like translucency, contrasting with its general transparency (fig. 8 B).

To cite another case, the actively motile zoöspores of the *Saprolegnia* which develops within the bodies of dead flies in fresh water will retain some movement even after they have been in a 0.625 molecular sodium chloride solution for 24 hours. In molecular magnesium sulphate they remain motile for more than 9 hours, but are never so active as the normal. In 0.625 molecular potassium chloride they are normally or even supernormally active for 4 or 5 hours, but after this their movements decline and die out after about 6 hours. In 0.166 molecular calcium chloride they move normally for about 2 hours and then stop.

The zygospores of *Fucus* illustrate another exceptional case. They move slowly for from 13 to 19 minutes in 0.625 molecular sodium chloride, gradually coming to rest. In 0.625 molecular magnesium sulphate they cease to move in from 4 to 8 minutes, and in solutions of potassium chloride they soon cease to move, strong solutions stopping them almost instantly. Altogether their reactions resemble those of the neuromuscular system of animals rather than animal cilia.

I have thus met with nothing but confusion in attempting to correlate the reactions of plant spores with those of animal cilia, but it is still possible that further study may demonstrate the existence of relationships in the reactions of certain special forms of plants to those of animals, but I doubt if any general significance can be attached to this even if it be a fact.

TABLE I.—*Neuro-muscular Movements.*

Effects of solutions composed of one or more of the constituents of van't Hoff's sea-water solution upon invertebrates. The complete solution is 0.625 *molecular* ($100NaCl+7.8MgCl_2+3.8MgSO_4+2.2KCl+2.5CaCl_2$).

Composition of solution.	Initial effect of solution.	Duration of movement in minutes.			Condition of muscles when movement has ceased.	Movement may be restored after it has ceased by addition of—
		Cassiopea.	Lepas.	Annelids.		
$NaCl$..........	The most powerful stimulant, causing marked initial increase in rate and vigor of movements.	45−	1 to 12	30 ±	Muscular tonus practically normal, being neither in tetanus nor relaxed.	Calcium readily restores temporary movements; potassium also does this but far less efficiently.
$NaCl+MgCl_2+MgSO_4$	Immediate and continued depression without initial stimulation.	0.75 to 6	20−	4 to 45	Muscles relaxed....	Calcium.
$NaCl+KCl$....	Stimulating, but to a lesser degree than a pure NaCl solution; though movement endures longer than in pure NaCl it is neither so rapid nor powerful.	120+	8 to 32	45 ±	As in NaCl........	Calcium.
$NaCl+CaCl_2$...	Stimulating, but not so actively as in NaCl, though movement lasts longer than in NaCl.	90−	9 to 75	40 to 300	Muscles in strong tetanus, which is clonic in case of Annelids.	Magnesium removes tetanus and restores movement.
$NaCl+MgCl_2+MgSO_4+CaCl_2$	Very slightly stimulating; nearly normal.	40−	50 to 220	Not recorded. About 300 minutes or more.	*Lepas* shows a slight tetanus. *Cassiopea* and Annelids come to rest, neither relaxed nor in tetanus.	Potassium exhibits a slight and only momentary restorative power.
$NaCl+MgCl_2+MgSO_4+KCl$	Movements decline steadily, but not so rapidly as in Na+Mg.	6−	20 to 45	19 to 70	Muscular relaxation.	Calcium.
$NaCl+CaCl_2+KCl$	Stimulating, but not so actively as in a pure NaCl solution, though movements endure longer.	250+	240 to 360+	240 to 420+	Tetanus, resulting in tearing apart of muscles of *Cassiopea*, strong contraction of muscles of *Lepas*, and tearing open of cuticula of Annelids, whose bodies come to rest in kinked and contorted folds.	Magnesium removes muscular tetanus and restores movement. This is more efficacious in case of medusa than in higher forms.

TABLE II.—*Ciliary Movements.*

Reactions of the cilia of Annelid worm larvæ and Veligers in solutions composed of one or more constituents of van't Hoff's sea-water solution. The complete solution is 0.625 ***molecular*** $(100NaCl+7.8MgCl_2+3.8MgSO_4+2.2KCl+2.5CaCl_2)$.

Composition of the solution.	Initial effect on cilia.	Duration of movement in minutes.	General behavior.
$NaCl$	Strongly depressed...............	0.5 to 20	An immediate derangement of ciliary movement. The cilia may even dissolve.
$NaCl+MgCl_2+MgSO_4$	Slower than normal, but faster and better sustained than in any other combination of two cations.	60 to 400+	At first the Annelid larvæ tend to swim in circles, but soon they recover and progress normally but slowly forward.
$NaCl+KCl$....	All ciliary movement stops immediately, but after 5 to 20 seconds recovery takes place and slow ciliary movement is regained.	30 to 60	Initial checking of ciliary movement is a characteristic of all solutions containing potassium. After recovery the cilia move *slowly.*
$NaCl+CaCl_2$...	Movement continues, slowly dying out, without an initial arrest.	30 to 90	Larvæ swim slowly but in a normal manner. Cilia never dissolve in solutions containing calcium.
$NaCl+MgCl_2+MgSO_4+CaCl_2$	There is no initial arrest of movement. Ciliary activity is slow at first but it continually augments until its rate is fully that of the normal.	1000 to 3000+	In *Spirobranchus,* body of larva degenerates while cilia continue to beat, but in palolo this does not occur and cilia beat normally.
$NaCl+MgCl_2+MgSO_4+KCl$	Ciliary movement stops at once, but after a few minutes movement is regained and finally becomes normal in rate.	1080 to 3000+	After initial arrest of movement, ciliary activity continually augments and becomes normal in rate, finally, however, declining, so that larvæ swim in circles shortly before they die.
$NaCl+CaCl_2+KCl$	In many larvæ ciliary movement is completely arrested for a few seconds, but recovery soon takes place and the larvæ move slowly.	40 to 2000	A few larvæ move in circles but most of them progress normally but slowly. In some cases ciliary movement is not wholly checked but merely reduced at start.
0.4 molecular $MgCl_2$	There is no initial arrest of movement. The cilia begin at once to beat at about a normal rate. After cilia have ceased to beat temporary activity may be restored by 0.625 molecular NaCl.	30 to 300	The muscular movements cease in less than 7 minutes and the cilia beat incessantly, independent of the control of the neuro-muscular system.
$MgCl_2+CaCl_2$	As in $MgCl_2$......................	25 to 270	As in $\frac{4}{10}$ molecular $MgCl_2$.
$MgCl_2+KCl$	The cilia stop instantly but recover after about 2 minutes and beat at about a normal rate.	40 to 180	The muscles give a few initial contractions and then stop, and the cilia then beat incessantly and without being controlled by the neuro-muscular system.
$MgCl_2+CaCl_2+KCl$	Ciliary movement is checked at first as in all solutions containing potassium, but after a brief initial pause the cilia begin to beat at an *abnormally rapid* rate.	50 to 350	As in $MgCl_2+KCl$.
$CaCl_2+KCl$...	The cilia are checked or stopped at first but revive and beat more slowly than the normal.	90 ±	The neuro-muscular system is quickly inhibited, so that the cilia beat independent of its control.

II.

EFFECT OF DIFFERENT TEMPERATURES ON THE MEDUSA CASSIOPEA, WITH SPECIAL REFERENCE TO THE RATE OF CONDUCTION OF THE NERVE IMPULSE.

By E. NEWTON HARVEY
Of Columbia University

5 text figures

THE EFFECT OF DIFFERENT TEMPERATURES ON THE MEDUSA CASSIOPEA, WITH SPECIAL REFERENCE TO THE RATE OF CONDUCTION OF THE NERVE IMPULSE.

BY E. NEWTON HARVEY.

During the summer of 1909 a partial study was made of the effects of temperature on the nerve and muscle tissues of the scyphomedusa *Cassiopea xamachana*. The excellence of this jelly-fish for experimental work has already been commented on by several writers. It lives in great numbers in the bottom of the moat surrounding Fort Jefferson, Tortugas. The water in the moat varies in depth from 3 to 5 feet at low tide with a difference between high and low water of less than 3 feet. The temperature of the water at the bottom, where the jelly-fish live, after a 2-days storm, was 27° C. on July 18, 7 a.m., the coolest weather this summer. I think this is the lowest temperature attained in the summer. Next day at 1 p.m. the temperature had risen to 30°, and next day, also at 1 p.m., it was 29.5°. The temperature on the very hottest days was not taken, but I think it may become as high as 32° to 33°, as the surface-water in the moat on such days is very warm to the touch. The average normal summer temperature of *Cassiopea* may therefore be placed at about 29°.

Since the temperature to which tropical animals are exposed is so uniform, it is not surprising to find that they are quite sensitive to even slight changes of temperature. However, *Cassiopea* offers such exceptional advantages in other respects that the experiments reported below were undertaken, even though the effects of a wide range of temperature could not be investigated.

I wish to express my sincerest thanks to Dr. Mayer for valuable suggestions and for the many opportunities which he gave me of carrying out the work described herein. I am also indebted to Dr. J. H. Hilderbrand, of the University of Pennsylvania, for assistance, especially in calculating the diffusion rates of $MgSO_4$ and CH_3COOH.

The investigations may be arranged under two heads: (1) The temperature limits of activity and thermal death-points of muscle and nerve. (2) The temperature-coefficients of pulsation and nerve conduction.

A third series of observations was made on the effects of inhibiting electrolytes at different temperatures, 10° apart. If the ions enter into combination with any substance in the muscle and the cessation of contraction is connected with the formation of some compound, for instance an ion-proteid, then we should expect contraction in the inhibiting solution to cease two to three times more rapidly with every 10° rise in temperature, according to van't Hoff's empirical rule for the increase in velocity of chemical reactions with rise of temperature.

There is one possible source of error in an experiment of this kind. We may not be able to distinguish between the time it takes for the ions to diffuse into the nerve-muscle tissue and the time for them to stop contraction, when present in sufficient concentration. It may be said, however, that the diffusion time is very small. The nerve-muscle layer of *Cassiopea* is thin, certainly less than 0.2 mm. A calculation of the time required for a 0.375 molecular $MgCl_2$ solution to diffuse across a distance of 0.3 mm. and reach 0.9 of the original (0.375 molecular) concentration on the other side gave a value < 1 minute. The diffusion constant for $MgSO_4$ in pure water was used, as none other was available. Acetic acid would diffuse through the same distance even more rapidly. The above calculation is very rough and is only of value in showing how short the diffusion time may be provided there is no resistance at the cell boundary.

There is positive evidence that considerable time is required for $MgCl_2$ and CH_3COOH to stop conduction in the nervous network. This network is epithelial in nature, external to the muscles, and directly in contact with the sea-water, yet *the muscles always cease to contract before the nerves cease to conduct.* Conduction continues about twice as long as contraction. We see, then, that diffusion of the electrolyte must play a very small part in the stoppage of nerve conduction in *Cassiopea.*

This is also true for the muscles, as is shown below. Let us compare the times required for different concentrations of CH_3COOH to inhibit contraction and conduction. The following is a table of inhibition times:

cc. $\frac{n}{10}$ CH_3-COOH to 100 cc. sea-water.	Molecular concentration.[1]	Contraction ceases, in minutes.	Conduction ceases, in minutes.
6	n/166	0.25	0.25
5	n/200	0.75	1.25
4.5	n/222	1	1.5
4	n/250	2	3.5
3.5	n/285	1.75	5
3	n/333	4	7
2.5	n/400	9	Not lost in 15 min.
2	n/500	Weak but not lost.	Not lost in 15 min.

We assume that CH_3COOH actually enters the muscle cells and that the presence of a definite concentration within makes any further contraction an impossibility. The problem is, in what time would this concentration be reached from varying concentrations on the outside. It takes nine minutes for $\frac{n}{400}$ CH_3COOH to stop contraction, yet less than one minute for $\frac{n}{200}$ CH_3COOH. Velocity of diffusion is proportional to the degree of concentration. The time values, one and nine, could not possibly be accounted for by the above law, so that the difference in time must be attributed to the concentration of the acid in affecting the tissue, and not to the diffusion rates for the respective concentrations.

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[1] A correction must be made for the alkalinity of the sea-water, which is very high at Tortugas. Red litmus paper is quickly turned blue. Phenolphtaleïn becomes faint pink.

So much for a vindication of the experimental method. As for the results, they have been in part stated in my preliminary report.[1] Using the sense-organs as the source of stimulus and a temperature interval of 24° to 34° C.[2] there is without doubt a very marked increased efficiency of both $MgCl_2$ and CH_3COOH in stopping both contraction and conduction at the higher temperature (34°). At 34° functioning ceases 2 to 2.5 times as soon as at 24°. This value is identical with van't Hoff's coefficient (2 to 3) for increase in velocity of chemical reactions with 10° rise of temperature.

Inasmuch as a similar value was not obtained with 20° to 30° as the 10° interval, and the stimulus given out by the sense-organs may have varied in strength at different temperatures, it has seemed better not to publish any data until further experiments can be made. It is hoped that they will afford sufficient evidence to decide the question.

TEMPERATURE LIMITS OF ACTIVITY AND THERMAL DEATH-POINTS OF MUSCLE AND NERVE.

METHOD.

The muscles and nerves of *Cassiopea* form a layer almost as thin as paper over the whole of the subumbrella surface, the nerves outermost. Although intimately connected and impossible to separate by dissection, the greater resistance of the nerves to temperature extremes renders possible a study of their properties apart from the muscles. This is done in the following way, first described by Mayer[3] in studying the effects of salts. A long strip of disk-tissue with several sense-organs on one end is laid across three dishes filled with sea-water (A, B, and C, fig. 1).

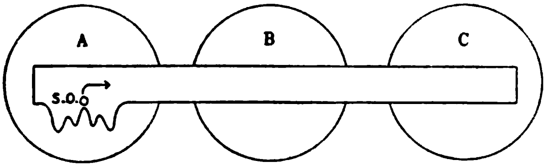

Fig. 1.

Stimuli are constantly arising in the sense-organs in dish A, and pass along the strip of tissue stimulating the muscles as they go. By slowly raising or lowering the temperature of the sea-water in B, a temperature can be found where contraction of the muscles ceases, yet the impulse is still transmitted. A cessation of nerve[4] conduction is indicated by the muscles in C, which can then no longer contract, except, of course, on direct stimulation.

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[1] Carnegie Institution of Washington, Year Book, No. 8, p. 117, 1909.

[2] 5° either side of the average summer temperature of the water at Tortugas.

[3] Mayer, A. G., Carnegie Institution of Washington, Pub. No. 102, p. 128.

[4] Conduction is assumed to take place always through the nervous network, inasmuch as it has not been shown for *Cassiopea* that conduction can take place through muscles independently of nerves.

The influence of temperature on the sense-organs apart from other tissues can be studied by the method indicated in fig. 2. The sense-organs are in A and the sea-water is slowly warmed. Cessation of contraction in B indicates that the stimuli are no longer given out by the sense-organs.

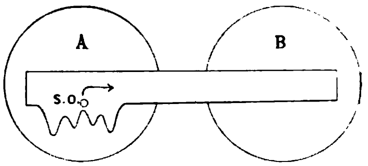

FIG. 2.

The thermometer used had been standardized and was graduated to 0.1° C. The rate of change of temperature was kept as constant as possible, 1.0° in 2 minutes.

LOWERING THE TEMPERATURE.

Cooling of the sea-water containing normal medusæ produces at first a rapid pulsation, but the rate per minute gradually decreases at lower temperatures. At about 18° *Cassiopea* begins to turn inside out, the subumbrella surface becoming convex and the exumbrella concave. This relaxation, as it may be called, is also characteristic of diseased (by parasites) and dying (in stale or constantly agitated sea-water) jelly-fish. The fact that it begins at 18° to 19° shows how sensitive the animal is to a decrease in temperature. The summer temperature of the sea-water at Woods Hole is about 18°, whereas on the California coast Loeb [1] reports the temperature of the water to be about 10° and the eggs of *Strongylocentrotus* fail to develop above 23°.

Using the methods illustrated in figs. 1 and 2, it was found that the functioning of three different tissues ceases at the following temperatures: sense-organs (pulsation), 14° C.; muscles (contraction), 9.5° to 10.6°; nerves (conduction), 8.8° to 9.5°.

If cooled to 9.5° and immediately returned to sea-water at 29° there is complete recovery, but there is no recovery if cooled to 7° to 8° C. The tissues disintegrate on warming, whether warmed suddenly or slowly. This fact is especially interesting, as, with the exception of warm-blooded animals, few forms are killed by exposure to low temperatures, but above the point at which ice crystals form.[2] Irreversible changes do not take place in all jelly-fish, however, as Romanes [3] reports freezing *Aurelia aurita* solid in a block of ice, yet there was complete recovery on thawing.

RAISING THE TEMPERATURE.

A sudden rise of temperature brings about a sudden increased pulsation of the normal medusa, but this increase is not so marked as with lowering. Relaxation begins about 36°. The tissues cease to function at about the following temperatures: muscles,[4] 39.5°; sense-organs, 42.6°; nerves, 44.0°.

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[1] Loeb, J., Arch. f. d. ges. Physiol., 124, p. 417, 1908.

[2] See Loeb's discussion in Dynamics of Living Matter, p. 110.

[3] Romanes, J. J., Jelly-fish, Star-fish, and Sea-urchins, International Scientific Series, New York, 1885, vol. XLIX, p. 167.

[4] The circular muscles cease perhaps 0.5° before the radial muscles, but this difference is not always constant.

If returned to sea-water at 29° from 44°, the nerves may partially recover at first, but later lose their power of conduction, while the muscles can still contract when stimulated by induced shocks. On returning to sea-water at 29° from 44.5° neither the nerves nor muscles recover. The strips eventually disintegrated. The heat stand-still of the sense-organs is also reversible until 44°, above which there is no way of telling whether recovery would occur or not.

At 39.5° the muscles are perfectly relaxed. Although unable to contract they do not pass into heat rigor. On still further raising the temperature the muscles remain in the same relaxed condition until about 55°, when they slowly contract. A large amount of whitish slime is given off during the heating. If this temperature corresponds to that of heat rigor in other animals it is exceptionally high. In skeletal muscles of the frog heat rigor occurs at 39°, in the mammal at 47°, and in the heart of Limulus at 48.5°.

If the tissues of *Cassiopea* are kept near their temperature limit for longer times, both contraction and conduction stop at lower temperatures. The upper temperature limit is therefore a function of time. In this connection two very interesting recent papers may be mentioned:

A. Meyer[1] has shown that the killing time for bacteria above the temperature at which life continues indefinitely may be calculated from the following equation:

$$x = aq^{n-1}$$

where

x = time of exposure

q = a constant for a given bacterium

a = the killing time at 80° C., the first of a series of terms 10° apart (80°, 90°, 100°, etc.).

n = the term in the series (80 = 1st term, 90° = 2d term, etc. For 100° $n-1=3-1$).

Calculated as Q_{10}, the temperature coefficient[2] is 5 for *Bacillus subtilis* and 4 for *Bacillus robur*. The reader is referred to the original paper for the values of q and a, which vary with each bacterium.

Loeb[3] has studied the temperature coefficient for the length of life of sea-urchin eggs at temperatures above normal. If the length of life for T degrees is known and is represented by D, then the length of life for a temperature $T-n$ degrees is 2^nD. Q_{10} was found to be about 1000. This is true for the unfertilized as well as the fertilized eggs. In both of these cases it will be seen that Q_{10} is constant for all 10° intervals. I mention them especially because there is another class of vital temperature coefficients in which Q_{10} varies according to the 10° interval. I shall speak of this and its meaning later.

It may be of interest to compare the temperature limits of activity of a tropical animal with those of a northern form. As the analogy between a heart and a medusa is very close, the temperature limits of an invertebrate heart have been selected.

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[1] Meyer, A., Berichte, d. deutsch. Bot. Gesell., XXIV, p. 340, 1906.

[2] Q_{10} is the ratio of a constant at T + 10 degrees to a constant at T degrees *C.*, or $Q_{10} = \frac{k_{t+10}}{k_t}$

[3] Loeb, J., Arch. f. d. ges. Physiol., 124, p. 417, 1908.

Carlson[1] gives the following temperatures at which activity ceases in the heart of *Limulus* from the region of Woods Hole. The effect of temperature on the heart ganglion, muscle, and nerves can be readily studied separately in this form:

Muscle	Contractions cease	0 to − 1° C.
	Optimum	10 to 14°
	Contractions cease	32°
	Tonus or heat rigor	47 to 50°
Ganglion	Stimuli cease	0 to −1° C.
	Stimuli cease	42°
	Ganglion killed	Above 47 to 50°
Nerves	Conduction ceases	−2° C.
	Conduction ceases	43°
	Nerves killed	Above 47°

It will be noticed that, although the normal temperatures of the two animals are very different (more than 10°) yet their upper temperature limits are nearly the same. *Cassiopea* is an animal living constantly within about 15° of its death-point, yet is not adapted to withstand higher temperatures than the heart of a northern animal living 25° to 30° from its death-point. The *Limulus* heart can withstand much lower temperatures than *Cassiopea*, however. This is what we might expect.

It would be interesting to determine the temperature limits for the heart of the *Limulus* which occurs around the Marquesas Keys, near Tortugas, and whose normal temperature is very different from that of the *Limulus* on which Carlson worked.

THE TEMPERATURE-COEFFICIENTS OF PULSATION AND NERVE CONDUCTION.

PULSATION.

Cassiopea is not a favorable object for a study of the influence of temperature on pulsation, because it is so readily excited to rapid beating, by handling, by currents of water, and by sudden though slight changes in temperature, both higher and lower than the normal summer temperature (29°). After some time this initial excitation caused by a change in temperature passes off and the beats become fairly constant. On account of the difficulty of obtaining and keeping ice at Tortugas, only a few observations on the pulsation rate were made.

An average of 6 counts gave the following as the number of pulsations per minute for 4 temperatures: 30°,−33 per minute: 25°,−26 per minute; 20°,−17 per minute; 16°,−8 per minute.

$$Q_{10}\ (20^\circ - 30^\circ) = \text{ca.}2 \qquad Q_{10}\ (16^\circ - 25^\circ) = 3$$

The coefficient is of the same magnitude as that for the increase in the velocity of chemical reactions per 10° rise in temperature. All observations thus far indicate that Q_{10} for the rate of increase of the heart beat, both of vertebrates and invertebrates, is about 2 to 3 for normal temperatures. We may conclude that in the medusa, as in the heart, the origination of stimuli in the sense-organs is dependent on the progressing of some chemical reaction.

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[1] Carlson, Am. Journ. Physiol., 15, p. 215, 1906.

Mayer[1] believes that the pulsation is due to a constant formation of sodium oxalate in the sense-organs. This precipitates the $CaCl_2$ and $CaSO_4$ diffusing it from the sea-water, thus forming a slight excess of NaCl and Na_2SO_4, which act as stimulants. The rate of formation of Na oxalate (probably from carbohydrates) conditions the rate of pulsation. This, then, appears to be, in part at least, the reaction whose increase in velocity with rise of temperature quickens the pulsation rate at the same time.

NERVE CONDUCTION.

With the exception of Maxwell's paper on the pedal nerves of *Ariolimax*, previous work on the influence of temperature on nerve conduction has been confined to vertebrates.

Snyder[2] calculated from Helmholtz's[3] observation on the frog a temperature-coefficient (Q_{10}) of 3.16; from Nicolai's[4] observations on the olfactory nerve of the pike a value for $Q_{10} = 2.6$; and from von Miriam on the frog's ischiadicus, $Q_{10} = 1.95$. In his own experiments, reported in the same paper, Snyder also determined Q_{10} for conduction rate in the frog's sciatic to lie for the most part between 2 and 3.

Lucas[5] finds in the leg nerves (sciatic + tibial + sural) of the frog Q_{10} for 8° to 18° and 9° to 19° = 1.64 to 2.08 with an average of 1.79.

Maxwell,[6] in 1907, working on the pedal nerves of *Ariolimax*, in which the conduction rate is slow, found Q_{10} to equal on the average 1.78.

In this connection it may be of interest to mention Wolley's[7] paper on the rate of conduction of a contraction wave in the frog's sartorius. The latent period is also recorded. His results are as follows:

	Rate of conduction of contraction wave.			Latent period of contraction.		
	Max.	*Min.*	*Aver.*	*Max.*	*Min.*	*Aver.*
Q_{10}(5°–15°).....	2.37	1.47	2.01	3.94	2.65	3.34
Q_{10}(10°–20°).....	2.03	1.46	1.79	4.47	2.78	3.51

The rate of conduction in muscle appears to be influenced by temperature to the same degree as nerve.

In *Cassiopea* the rate of nerve conduction is very much more uniform than that of pulsation. It is not affected by currents in the sea-water or by slightly disturbing the piece of tissue. Transferring from one dish of sea-water to another slows the conduction while in the air, but nearly the original rate is regained again in sea-water. A more favorable object for the study of nerve conduction could not be desired.

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[1] Mayer, A. G., Carnegie Institution of Washington, Pub. No. 102, p. 129.

[2] Snyder, C. D., Am. Journ. Physiol., 22, p. 179, 1908.

[3] Helmholtz, Müller's Archiv, 1850, pp. 345, 358.

[4] Nicolai, Arch. f. d. ges. Physiol., 85, p. 113, 1901, and Snyder, Arch. f. Anat. u. Physiol., Phys. Abt., p. 113, 1907.

[5] Lucas, K., Journ. Physiol., 37, p. 112, 1908.

[6] Maxwell, S. S., Journ. Biol. Chem., 3, p. 359, 1907.

[7] Wolley, W. J., Journ. Physiol., 37, p. 112, 1908.

For the following experiments ring-shaped pieces of tissue, without sense-organs, are cut from the disk, as has been described by Mayer.[1] If these are stimulated strongly at one point (S) by induced shocks, a nerve impulse passes around each side of the ring and the two block on the opposite side (fig. 3). If one impulse is itself blocked (fig. 4) by pressing on the nerves, for a moment, with a glass rod near the point of stimulation, the impulse of the opposite side will travel around the ring (stimulating the muscles as it goes) indefinitely, since it meets no counter impulse to stop it. Mayer has recorded rings of *Cassiopea* started in this way conducting for several days with a practically constant rate.

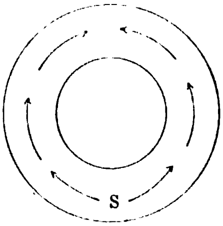

FIG. 3.

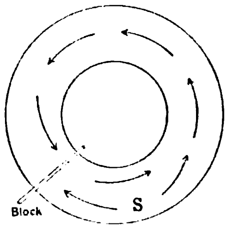

FIG. 4.

Below 18° it was found difficult to start impulses that would keep going. Even when the ring was first cooled and then stimulated, the impulse stopped suddenly after a few seconds. Between 18° to 38°, however, an accurate temperature conduction rate curve could be plotted. All the readings on curve *A* (fig. 5) have been obtained from one ring which was started at 17° and then gradually warmed at an average rate of 1.0° in 4 minutes.

Temperatures are plotted as abscissæ; conduction rate (*i.e.*, the number of times per minute the nerve impulse passes around the ring of tissue) as ordinates. The outside diameter of the ring was 104 mm. and its inside diameter 61 mm. The following table gives actual velocities of propagation for a few temperatures in millimeters per second:

	18°	20°	25°	30°	33° (max.)	35°	38°
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Velocity about inner portion	136	178	276	371	401	391	324
Velocity about outer portion	234	304	469	635	707	669	553

It is interesting to note that the conduction wave, to pass around the ring regularly, must move much more rapidly on the outer than the inner side. There is apparently some coördinating mechanism regulating the velocity of the impulse in different regions of the subumbrella. If a conducting ring be cut in two the original velocity is not maintained in each new ring, *i.e.*, the new rings do not remain synchronous.

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[1] Carnegie Institution of Washington, Pub. No. 102, p. 117.

Curve B was plotted from data obtained with a ring whose outside diameter = 75 mm.; inside diameter = 30 mm. Its form is essentially that of A, but it is less regular. This must be attributed to experimental errors, as my apparatus for changing the temperature uniformly was not as perfect as in the experiment from which A was plotted, and the thermometer used was only graduated to degrees instead of 0.1 degree.

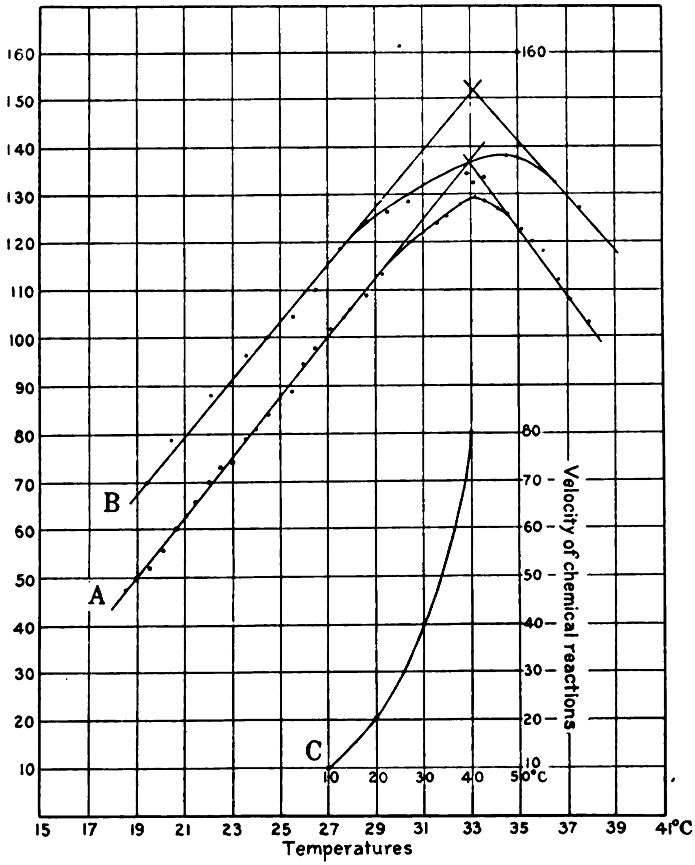

FIG. 5.

The values of Q_{10} for 10° intervals along curve A are as follows:

18 to	28 degrees	2.40 Q_{10}	24 to	34 degrees	1.58 Q_{10}
19	29	2.24	25	35	1.41
20	30	2.08	26	36	1.25
21	31	1.93	27	37	1.10
22	32	1.82	28	38	0.96
23	33	1.73			

So long as the temperature-velocity curve is a straight line, the value of Q_{10} will not be constant for all 10° temperature-intervals, but will gradually become less and less, the higher the temperature. This is not the case (as a rule) for temperature-reaction velocity curves. Q_{10}

is very much more nearly a constant for all 10° temperature-intervals,[1] although it does vary somewhat, and differently for different reactions.[2] Curve C (fig. 5) may be taken as the type for increase in reaction velocity with rise of temperature. It has been so plotted as to be easily compared with A and B. For this curve $Q_{10} = 2$, constant at all temperatures.

If the rate of nerve conduction depends on the velocity of some chemical reaction in the nerve, the above-mentioned difference in its temperature curve remains to be explained. It is possible, indeed probable, that yet another factor than reaction velocity determines conduction rate, and the resultant curve of the two factors is the one actually observed. The velocity of enzyme actions, which show similar characteristics, will be spoken of later.

Q_{10} for the rate of heart beat of the Pacific terrapin, as given by Snyder,[3] also decreases rapidly, the higher the 10° temperature interval. The curve as given by Wolley for the velocity of a contraction wave in the frog's sartorius is only slightly curved and the average value of Q_{10} for 5° to 15° is 2.01 as compared with 1.79 for 10° to 20°.

Snyder's observations on the frog's sciatic nerve, before mentioned, also point to a right-line temperature curve of nerve conduction in this animal. He gives the following as a typical case (p. 196).

Temp.	0°		10°		20°		30°
Velocities	2.9(X)		11.3(Y)		28.3(Y)		44(X) m. per sec.
Q_{10}		3.9		2.5		1.5	

Snyder explains the above as follows:

The velocity of the nerve impulse is assumed to depend on the velocity of more than one reaction in the nerve, let us say *X* and *Y*. If reaction *Y* proceeded throughout the range of temperatures (0° to 30°) we might have corresponding nerve-impulse velocities of 4.5, 11.3, 28.3 and 70 meters per second. Its temperature coefficient would be 2.5. With reaction *X* proceeding, we might have nerve-impulse velocities of 2.9, 7.2, 18, and 44, corresponding to the four temperatures. The coefficient for *X* is also 2.5. Now if reaction *X* only proceeded at 0° and 30° and reaction *Y* at 10° and 20°, the result indicated above would be attained.

It is hard to see, however, why *X* should function at 0°, then cease, and then begin again at 30°, and it seems highly improbable that any such change would occur. The decrease in Q_{10} with increasing temperature is inevitable so long as the temperature-conduction curve is a straight line (as it is between 17° to 29° in *Cassiopea*). There is no way of combining the velocities of two reactions having the same temperature-coefficient, and obtaining a straight line. It is also noteworthy that there are no critical points between 17° to 29°, such as we might expect were a radical change in the reaction at the basis of nerve conduction to take place.

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[1] See the velocities of reactions as given by Snyder in Univ. Cal. Pub. Physiol., 2, p. 136, 1905.

[2] As a rule the ratio of $\frac{K_{t+10}}{K_t}$ falls off very slightly with rise of temperature. See van't Hoff, Lectures on Theoretical and Physical Chemistry, London, p. 228.

[3] Snyder, C. D., loc. cit., p. 141.

The characteristic maxima, at an optimum temperature, exhibited by curves A and B (fig. 5) require a word of comment. Maxima occur in all temperature curves of vital processes. A maximum is also exhibited by temperature curves of enzyme action. In fact the curves for enzyme action as given in Cohen's Physical Chemistry[1] are very similar to curves A and B. *There is the same falling off in calculated (if Q_{10} were a constant) velocity, the higher the temperature until a maximum is reached.*

Different enzymes exhibit maxima at different temperatures. Most of these are rather high, much higher than the maximum for nerve-conduction, which lies at about 33° C. The same ferment obtained from different sources may exhibit different maxima. For instance, the indigo enzyme obtained from *Indigofera heptostacha* has a maximum at 61° C.; from *Polygonum tinctorium*, 53° C.; from *Phajus grandiflorus*, 42°; and from *Saccharomyces sphœricus*, 44°. Cohen explains this as meaning that the optimum depends on the medium containing the ferment. If we may assume that conditions in the nerve are such as to give a very low optimum, then we may say that the propagation of the nerve impulse is not only dependent on the velocity of a chemical reaction, *but that the reaction is further accelerated by the presence of an enzyme.* Thus the characteristic difference in the form of curve from that of a simple chemical reaction.

The maximum for enzyme actions is generally interpreted as the point beyond which the enzyme begins to undergo decomposition with consequent falling off in the reaction velocity, even though the temperature is continually increased.[2] Taylor[3] regards all reactions as having an optimum temperature at which the velocity is a maximum, only in enzyme action this temperature is low. Blackman points out that in a process proceeding at a certain rate (*e.g.*, a reaction) and dependent on several factors, any one of the factors may become a limiting factor for the process in question.

Whatever the explanation may be, it is interesting to find that nerve conduction exhibits a falling off in rate with rise of temperature to a definite maximum, similar to that for enzyme action and for other life processes.

A literature list of the effect of temperature on vital processes interpreted with respect to van't Hoff's coefficient (Q_{10}) is given by Loeb, Robertson, Maxwell, and Burnett in Science, N. S., 28, p. 647, 1908. References to literature on this subject are also given in Cohen's Physical Chemistry, translated by Fischer, New York, 1903, pp. 50–67.

Cases of vital processes exhibiting chemical temperature-coefficients have been collected by Kanitz, A., in Zeit. für Elektrochemie, 13, p. 707, 1907, and Snyder, C. D., in Am. Jour. Physiol., 22, p. 309, 1908. The reader is referred to the above four papers for the literature on this subject.

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[1] Translated by Fischer, p. 56.

[2] For a discussion of the meaning of an optimum temperature, see Blackman, Annals of Botany, 19, p. 281, 1905, and Am. Nat., 42, p. 659, 1908. Also Bayliss, Nature of Enzyme Action, in Monographs on Biochemistry, p. 52, 1908.

[3] Taylor on Fermentation in Univ. of Cal. Pub. Pathology I.

III.

THE INFLUENCE OF REGENERATING TISSUE ON THE ANIMAL BODY.

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3 text figures.

THE INFLUENCE OF REGENERATING TISSUE ON THE ANIMAL BODY.

By Charles R. Stockard.

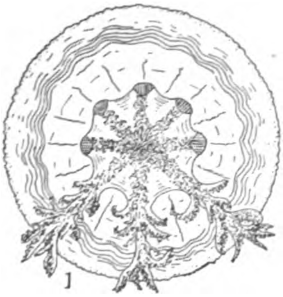
When the adult animal body begins to regenerate new tissue in order to replace a lost part, or when abnormal secondary growths arise, the condition of growth-equilibrium is disturbed and such a disturbance is followed by changes which affect the usual physiological condition of the body. The question arises whether the changes following or accompanying normal regenerative growth are in any way similar to those effects resulting from malignant or abnormal secondary growths. If one believe, with many pathologists, that cancerous formations are growths of a secondary nature induced by some derangement in the normal growth states, and are not of infectious origin, then normal secondary growths, in some stages at least, should affect the body in a manner somewhat similar to that resulting from an active tumor growth. The emaciated or cachectic conditions of the body resulting from the effects of cancerous growths are not always thought to be attributable to toxins or substances taken into the circulation from the cancer, but at times seem to be due to the excessive appropriation of nutriment and energy by the rapidly growing cancer itself. A malignant tumor continues to grow and so finally kills the body, while on the other hand the regenerating part, although rapidly growing at first, gradually decreases in growth rate and begins to differentiate and function, thus diverting the energy previously used in the growth processes.

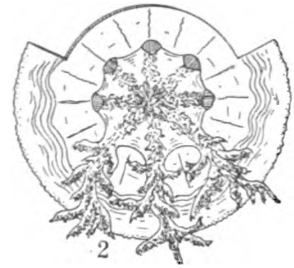
I showed in the second of my "Studies of Tissue Growth" (Jour. Exp. Zool., vol. VI, 1909) that the medusa disk of *Cassiopea xamachana* decreased rapidly in size while regenerating new oral-arms, and that the rate of decrease was faster in those specimens regenerating the greater number of parts. In these experiments a source of error was realized, since those specimens with 6 or 8 oral-arms removed might have been deprived of more reserve food held in the oral-arms than had the individuals which lost fewer arms. I determined to control this condition by operating on medusæ so as to remove the same number of oral-arms from all and to increase the amount of new regenerating tissue in some individuals by also removing a part of the disk. The specimens were kept under identical conditions and were not fed during the time of the experiment. Thus any difference in their responses is due only to the additional amount of regeneration imposed upon the individuals with the cut disks.

Emmel (36th Ann. Rep., Inland Fisheries of Rhode Island, 1906) has contributed an observation which is most interesting in connection with these experiments. He found that when larval lobsters were regenerating new legs they molted after longer intervals than normal individuals, and grew in size at a rate sometimes 24 per cent slower than the non-regenerating specimens. Most important was his observation that when the removal of legs was *not* followed by regeneration such specimens grew in size faster than the regenerating individuals, and in most instances actually faster than the control. These observations clearly show that the process of regeneration itself, and not the injury inflicted, is responsible for the retardation of growth in the regenerating lobsters.

The experiments here recorded were performed upon the Scyphomedusa *Cassiopea xamachana*, which may be so readily obtained at the Tortugas Islands. Healthy individuals of medium size were selected and operated upon as described below.

The first experiment consisted of two groups of 20 individuals of the same average size. Group A had 5 of the 8 oral-arms cut from each specimen (fig. 1). Group B also had 5 oral-arms cut in a similar manner from each of the 20 individuals, and in addition each medusa had a peripheral strip cut from its body disk which included one-third of the circumference and in width extended in beyond the oral, zigzag, muscular layer shown in fig. 2. The specimens were then allowed to regenerate for 34 days, their disk diameters being measured at intervals so as to determine the differences in decrease of body size in the two groups.





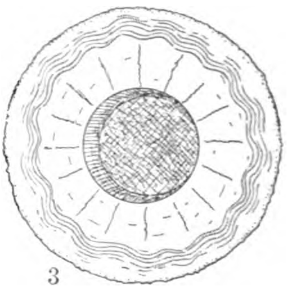


FIG. 1.—Medusa with 5 oral-arms cut away at their bases.
FIG. 2.—Medusa with 5 oral-arms cut away and a peripheral strip cut from the disk.
FIG. 3.—Medusa disk after all of the oral-arms and the stomach have been removed.

TABLE I.—*Record of disk diameters and regeneration of oral-arms in Cassiopea, when 5 arms are removed (in millimeters).*

Disk diameter May 15.	Disk diameter May 27.	Length of arm-buds May 27.	Disk diameter June 4.	Length of arm-buds June 4.	Disk diameter June 12.	Length of arm-buds June 12.	Disk diameter June 18.	Length of arm-buds June 18.
95	80	3-3-4 -4-4	73	4-4-4-5-5	65	5-5-6-6-6	60	6-6-6- 6- 7
85	75	3-3-4 -4-5	67	5-5-5-6-6	61	5-6-6-6-7	57	6-7-7- 8- 9
82	68	4-4-4.5-5-5	60	4-5-6-6-7	55	5-6-6-6-7	51	6-7-7- 7- 8
90	75	4-5-5 -5-5	64	5-5-5-5-6	58	6-7-7-7-8	54	6-7-7- 8- 9
90	73	4-4-4 -5-5	64	5-5-6-6-6	58	5-6-6-6-7	55	6-7-7- 7- 8
75	63	4-4-4 -4-4	53	4-5-5-5-5	47	5-5-5-6-6	44	5-5-6- 6- 6
80	68	3-4-4 -5-5	60	5-5-5-5-6	53	5-5-5-6-6	48	5-5-5- 6- 6
75	63	4-4-5 -5-5	55	5-5-5-5-6	49	5-5-5-5-6	45	5-5-6- 6- 6
75	59	4-5-5 -5-5	52	5-5-6-6-6	47	4-5-5-6-7	44	5-6-6- 6- 7
80	72	4-4-4 -4-4	64	5-5-6-6-6	57	6-6-6-7-7	54	6-6-7- 7- 7
75	61	4-5-5 -6-6	54	5-6-6-6-6	49	5-5-6-6-6	44	4-5-5- 6- 6
72	60	5-5-5 -5-6	53	4-5-5-5-5	48	5-6-6-6-6	44	6-6-6- 7- 7
80	64	5-5-5 -6-6	56	6-6-7-7-7	51	8-8-8-8-9	47	9-9-9- 9-10
80	63	5-5-6 -6-6	57	7-7-7-7-8	53	8-8-8-8-9	49	9-9-9- 9-10
75	60	5-5-5 -6-6	50	5-5-5-5-5	44	7-7-7-7-8	41	7-8-8- 8- 8
85	71	4-4-5 -5-5	64	5-5-5-6-6	58	5-6-6-7-7	54	6-7-7- 8- 8
75	61	3-5-5 -5-6	54	5-5-5-5-6	47	5-6-6-6-6	44	5-6-6- 6- 6
90	76	5-5-5-5.5-5	66	5-6-6-6-7	61	6-6-7-8-8	57	7-8-8- 9- 9
70	58	4-5-5 -5-6	49	5-5-6-6-7	44	6-6-6-7-7	40	6-6-6- 7- 7
100	80	4-5-5 -5-5	70	5-6-6-6-6	66	6-7-7-8-9	63	8-9-9-10-10
Av. 81.5	67.5	4.7	59.3	5.5	53.5	6.3	49.7	6.9

Table I shows the records for group A, the first column giving the original disk diameters, the second column the diameters after 12 days, the third column the length of the individual new arm-buds regenerated during the 12 days. The fourth column gives the diameters after 20 days and the fifth column the length of the new arm-buds at this time. Columns six and seven show the same after 28 days and columns eight and nine after 34 days when the experiment ceased. A line of averages at the foot of the table shows the general result.

Table II gives the same data for Group B and a comparison of the tables is facilitated by table III of averages.

The individuals of both groups averaged 81.5 mm. in diameter at the beginning of the experiment, and after 12 days the specimens of Group A were 67.5 mm. in diameter, while those in Group B, which were regenerating the disk-tissue in addition to the 5 oral-arms, were only 64.3 mm. in average diameter. In other words they averaged 3.2 mm. smaller than the ones growing only the 5 arms. After this time, however, Group B did not decrease so rapidly, since the disk injury had almost completely regenerated: thus after 20 days the A group was only 1.7 mm. larger than B, after 28 days only 1.2 mm. larger, and after 34 days there was still only 1.3 mm. difference in average size.

TABLE II.—*Record of disk diameters and regeneration of oral-arms in Cassiopea, when 5 arms and a part of the disk are removed (in millimeters).*

Disk diameter May 15.	Disk diameter May 27.	Length of arm-buds May 27.	Disk diameter June 4.	Length of arm-buds June 4.	Disk diameter June 12.	Length of arm-buds June 12.	Disk diameter June 18.	Length of arm-buds June 18.
95	78	3-3-4-4-4	70	4-5-5-6-6	63	7-8-8-8-8	59	9-9-9-9-9
85	70	3-3-3-3-4	62	5-5-6-6-6	56	6-6-6-7-9	51	8-8-8-9-9
82	65	4-4-4-5-5	58	5-5-6-6-6	52	5-6-7-7-8	47	7-8-8-8-8
90	69	4-4-3-3-3	59	4-5-5-5-5	53	4-5-5-5-5	48	4-4-4-5-5
90	73	3-3-3-4-5	65	3-3-3-4-4	59	4-4-4-5-6	57	4-4-4-5-5
75	59	3-3-4-4-5	54	6-6-6-6-6	50	5-5-5-6-6	46	6-6-6-7-7
80	60	2-4-4-4-5	55	4-5-6-6-6	49	5-5-6-7-7	45	6-6-7-7-7
75	60	4-4-5-5-6	54	5-6-6-6-6	48	5-5-6-6-6	44	6-7-7-7-8
75	55	3-3-4-4-4	50	5-5-6-6-6	45	5-6-6-6-7	41	5-5-6-6-6
80	63	4-4-4-5-6	57	5-5-5-6-6	54	5-6-7-7-7	49	7-7-7-7-7
75	60	3-3-4-4-5	56	6-6-6-6-6	51	6-7-7-7-8	47	7-7-7-7-8
72	55	5-5-5-5-5	50	6-6-6-6-7	46	6-7-7-7-7	42	6-8-8-8-8
80	66	4-4-5-5-5	60	6-6-7-8-8	54	6-6-7-7-8	49	6-7-7-8-8
80	57	5-5-5-5-5	50	6-6-6-6-7	45	6-6-6-7-7	41	5-5-6-6-7
78	57	4-5-5-5-6	51	5-6-6-6-6	45	7-7-7-7-7	42	7-7-7-7-7
87	70	2-3-4-4-5	62	3-4-5-5-6	56	3-5-6-6-7	52	5-7-7-8-8
72	59	3-5-5-5-6	52	5-6-6-7-7	48	7-8-8-9-9	45	6-9-9-9-9
90	70	3-3-4-4-5	62	3-3-3-4-4	58	2-3-4-5-5	53	2-4-5-6-7
70	57	4-5-5-5-5	50	5-5-6-6-6	44	7-7-8-8-8	42	7-7-8-8-8
100	84	0-3-3-4-4	76	*0-4-4-5-6	71	*0-5-6-6-7	67	*0-8-8-9-9
Av. 81.5	64.3	4.1	57.6	5.4	52.3	6.25	48.4	*f* 6.9

* Not included in the average.

f Oral-arms now branching so that the linear measurement does not indicate the entire amount of growth.

TABLE III.—*Summary of Tables I and II for comparison.*

Group.	Original diameter.	After 12 days.	After 20 days.	After 28 days.	After 34 days.
Diameters in mm.:					
A..............................	81.5	67.5	59.3	53.5	49.7
B..............................	81.5	64.3	57.6	52.3	48.4
Length of arm-buds in mm.:					
A..............................	81.5	4.7	5.5	6.3	6.9
B..............................	81.5	4.1	5.4	6.25	6.9

The experiment clearly shows that, while the B group was regenerating the cut disk part in addition to the 5 oral-arms, the individuals of B were decreasing in body size, as a result of this additional regeneration, more rapidly than the specimens in A which were regenerating only the 5 oral-arms. The regenerating tissue, through an excessive capacity for the absorption of nutriment, draws upon the old body tissues and causes them to decrease in size very much as one may suppose the rapidly growing tumor to impose upon the substances of the surrounding body. It is certainly clear that in both cases the growing tissue causes the old body to become weak and emaciated while the growth itself continues in a vigorous manner.

The above experiment is of further value in regard to the influence of the degree of injury on the rate of regeneration. I have previously shown (*loc. cit.*) that the rate of oral-arm regeneration in this medusa is independent of the degree of injury, as is also the case in the brittle-star, *Ophiocoma riisei*, while *O. echinata* regenerates each arm the slower the greater the number of removed arms. These results are contrary to Zeleny's idea that the greater amount of injury will be followed by a more rapid regeneration.

The two groups of individuals A and B are each regenerating 5 oral-arms, but the group B is the more extensively injured since a portion of the disks was also cut away. If the additional injury or regeneration imposed upon the B group exercises any influence on the rate of regeneration, it should be shown by comparing the rates of growth of the arm-buds in the two groups. The lower lines of table III give this comparison. Those specimens with the disk uncut, or the least-injured ones, regenerated slightly more rapidly during the first 12 days, but after this time the rates were practically equal. These facts show that an increased injury to the medusa fails to give an increase in the subsequent regeneration rates.

A second experiment differed somewhat in manner of operation from the one just described, yet the results are in perfect accord. Twenty-eight healthy medusæ were arranged in two groups of 14 individuals each and operated upon as follows: The specimens of Group I had all of their oral-arms and the central stomach mass entirely removed, leaving only the medusa disk (fig. 3). Such a preparation lives and pulsates in a normal manner and regenerates new tissue to cover over the central stomach space. Then new oral-arms begin to bud from this tissue, until finally the medusa regains its normal organs and parts. The central space is first covered by a thin veil of tissue which tears repeatedly and reforms until it begins to thicken, and then the new arm-buds first appear. The regenerative growth is therefore very vigorous from such specimens during the early part of the experiment, and later becomes much less. Group II was operated upon in the same manner as the specimens of Group B in the above experiment, 5 oral-arms and a part of the medusa disk were cut away (fig. 2).

Tables IV and V contain the data from these specimens and table VI facilitates a ready comparison of the averages. The original diameters of each group averaged 88 mm.; after 14 days Group I was only 62 mm.

in diameter while Group II was 69 mm., or 7 mm. larger. After 22 days they were 55.3 mm. and 63 mm., and after 28 days 51 mm. and 59 mm. It will be noted, however, that Group I ceased to decrease rapidly after the first 14 days, when its rapid regeneration also ceased, and from this time on it decreased almost as slowly as Group II, since in the last 6 days of the experiment it lost only 4.3 mm., while Group II lost 4 mm.

The rate of growth for the arm-buds in table v is practically the same as from the specimens similarly injured in the previous experiment.

Groups I and II again show that when a specimen regenerates a certain amount of tissue in a given time such a specimen suffers a loss in body size which is greater than the loss from other specimens regenerating a less amount of tissue. Regenerating tissue, therefore, consumes the old body-substance and has an effect which would finally so weaken the body as to cause death should the regeneration continue for a sufficient time. A method which could eliminate the factors that cause growth to cease when an organ has attained a certain size would allow the organ to grow at the expense of the other body parts until death would follow in a manner closely similar to that by which a malignant tumor growth finally kills the body containing it. The absence of certain of the growth-inhibiting substances in the body may be responsible for the indefinite cancer growths, and experiments that in any way lead to a determination of the controlling factors in normal, primary, or secondary growths are of great importance in this regard.

TABLE IV.—*Record of disk diameters and regeneration from Cassiopea, when all of the oral-arms and the stomach are removed (in millimeters).*

Disk diameter May 20.	Disk diameter June 3.	Regeneration June 3.	Disk diameter June 11.	Regeneration June 11.	Disk diameter June 17.	Regeneration June 17.
90	65	Central space covered.	58	Small arm-buds.	53	Well-formed buds.
85	60	Covered, hole in aboral center.	55	Well-formed arm-buds.	51	Arm-buds 4 mm. long.
95	66	Covered central space.	56	No arm-buds.	51	Small arm-buds.
85	59	Covered central space.	54	No arm-buds.	50	Small arm-buds.
90	62	Covered central space.	55	No arm-buds.	49	Arm-buds 3 mm. long.
100	72	Covered central space.	65	No arm-buds.	61	No arm-buds.
80	53	Covered central space.	48	Well-formed buds.	44	Arm-buds 3 mm. long.
72	52	Covered, arms budding.	46	Arm-buds 4 mm. long.	42	Arm-buds 5 mm. long, new stomach, etc.
92	64	Covered central space.	56	No arm-buds.	52	No arm-buds.
92	69	Covered central space.	61	Well-formed buds.	56	Well-formed arm-buds.
85	55	Covered central space.	51	Small arm-buds.	47	Small arm-buds.
90	61	Covered central space.	55	No arm-buds.	51	Small buds and stomach.
93	62	Hole in aboral center.	55	Small arm-buds.	52	Small arm-buds.
92	65	Hole in aboral center.	59	No arm-buds.	56	No arm-buds.
Av. 88.6	62		55.3		51	

TABLE V.—*Record of disk diameters and regeneration of oral-arms in Cassiopea, when 5 arms and a part of the disk are removed (in millimeters).*

Disk diameter May 20.	Disk diameter June 3.	Length of arm-buds June 3.	Disk diameter June 11.	Length of arm-buds June 11.	Disk diameter June 17.	Length of arm-buds June 17.
90	70	3-4-4-5-5	65	4-4-5-5-6	59	6-6-6-7-7
85	65	4-4-4-5-5	61	4-5-5-6-6	58	6-6-6-7-8
95	78	2-3-3-4-4	70	3-4-4-5-5	65	4-5-5-6-6
80	63	3-4-4-5-5	56	4-6-6-6-7	53	6-7-7-8-8
90	69	4-4-5-5-6	63	5-6-6-6-7	60	6-7-7-8-9
100	75	3-3-5-5-5	71	3-4-5-6-6	67	5-6-6-7-8
80	61	2-3-5-5-5	56	2-5-6-6-7	52	3-5-6-8-8
72	59	3-5-5-6-6	52	5-5-6-6-6	47	5-5-5-5-5
92	73	3-3-4-5-*	66	2-3-5-6-*	61	3-3-5-6-*
92	75	3-3-3-4-5	66	4-5-5-6-6	62	4-5-5-5-6
82	65	3-3-3-5-5	61	5-5-5-6-6	59	5-6-6-7-7
90	70	*f* 0-0-2-4-4	64	*f* 0-0-5-5-5	60	*f* 0-0-5-6-6
93	70	3-3-4-4-5	64	5-5-5-6-7	60	5-6-6-7-8
92	74	4-4-5-5-6	67	5-5-6-6-6	62	6-6-6-7-8
88	69	4.1	63	5.2	59	6

* Not regenerated. *f* Not included in the average.

TABLE VI.—*Summary of Tables IV and V for comparison.*

	Group I.	Group II.
Original diameter in millimeters	88.6	88
Diameter after 14 days	62	69
Diameter after 22 days	55.3	63
Diameter after 28 days	51	59

IV.

CRADACTIS VARIABILIS: AN APPARENTLY NEW TORTUGAN ACTINIAN.

By CHARLES W. HARGITT,
Of Syracuse University.

1 plate.

CRADACTIS VARIABILIS: AN APPARENTLY NEW TORTUGAN ACTINIAN.

By Charles W. Hargitt.

Dr. J. F. McClendon, during his stay at the Tortugas Laboratory of the Carnegie Institution of Washington, collected a few actinians for some experiments on behavior, which he afterward preserved and later turned over to the writer for identification. This I was very glad to undertake, but found the task somewhat more difficult than had been anticipated, owing chiefly to lack of some of the older literature pertaining to the region and to the fact that the specimens were in a rather poor state of preservation. Fortunately, however, Dr. McClendon had made photographs of the specimens in the living conditions of his aquaria, a few of which appear in the accompanying plate. Details of internal morphology I shall defer till a later time, hoping that additional material may enable me to make it more accurate and adequate.

There seems to be no doubt as to the place of the species in the family Phyllactidæ; concerning the generic relations I find myself more or less uncertain. There are phases of likeness with several genera, *e.g.*, *Lebrunia* Duch. and Mich., *Oulactis* M. Edw., and *Cradactis* McMurrich. But with none of these is there such close correspondence as to induce any considerable assurance. The 6 to 8 dichotomously branched fronds and its habitat in holes and crevices in coral rocks, which Verrill emphasizes of *Lebrunia*, have much in common with the species under consideration. On the other hand, when he says, "The species examined by me has, on these fronds, at the forks, many more or less spherical bodies having the structure of acrorhagi," there is at once lack of correspondence. And a further comparison of McMurrich's description of *Lebrunia neglecta* (Journ. Morph., vol. III, p. 33) makes it almost certain that the present species can hardly belong under *Lebrunia*.

The characters of *Oulactis*, especially the longitudinal rows of verrucæ and the more or less circumscribed sphincter, are rather sharply in contrast with the very smooth walls and diffused sphincter of the present species and would seem to preclude this genus from serious consideration.

As to the genus *Cradactis* as defined by McMurrich,[1] there are also several difficulties. For example, the fronds of *Cradactis* are defined as "bunches of tentacle-like structures," the walls are dotted with verrucæ, and the sphincter is circumscribed. None of these characters is distinctive of the present species. But in view of the fact that McMurrich himself has defined his genus in a somewhat tentative way, and admits the lack of conformity as to the sphincter character, I am disposed to refer the species provisionally to the genus *Cradactis*, no representative of which I have seen, till such time as further facts may call for other adjustment.

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[1] Proc. U. S. Nat. Mus., vol. XVI, p. 197.

So far as I have been able to ascertain, the species has not been hitherto described. I propose for it the specific name *variabilis*, as indicative of the extremely variable features exhibited. The following may be regarded as fairly diagnostic, so far as one may make up a definitive account from poorly preserved material. It may be said, however, that I have had the advantage of such verbal account as Dr. McClendon was able to give from memory.

Column low, in preserved specimens (McClendon gives it as his impression that in expansion it is about twice the diameter), smooth, with broader base than oral disk, the latter concave, with raised mouth which is oval in shape and as usual diglyphic. Tentacles somewhat finger-like, but in extension tapering to a delicate tip, about 30 to 40 in number or more in the largest specimens. The most remarkable feature is the peculiar frond-like organs situated about the margin of the oral disk and just outside the outer cycle of tentacles. There are usually 6 of these organs, more or less symmetrically arranged, though the number varies considerably, being frequently but 5 and sometimes as many as 7. Typically these are dichotomously forked once or occasionally twice, and the tips usually knobbed, as shown in some of the figures in the plate. Upon the upper surface of these organs there is usually a whitish disk or pad, sometimes several. These are shown in section to be glandular organs, and possibly secrete a substance, probably of an adhesive nature, such as might aid the creature in capturing prey. They are also provided with several large nematocysts, and the production and discharge of these may be an important, perhaps the most important, function they serve.

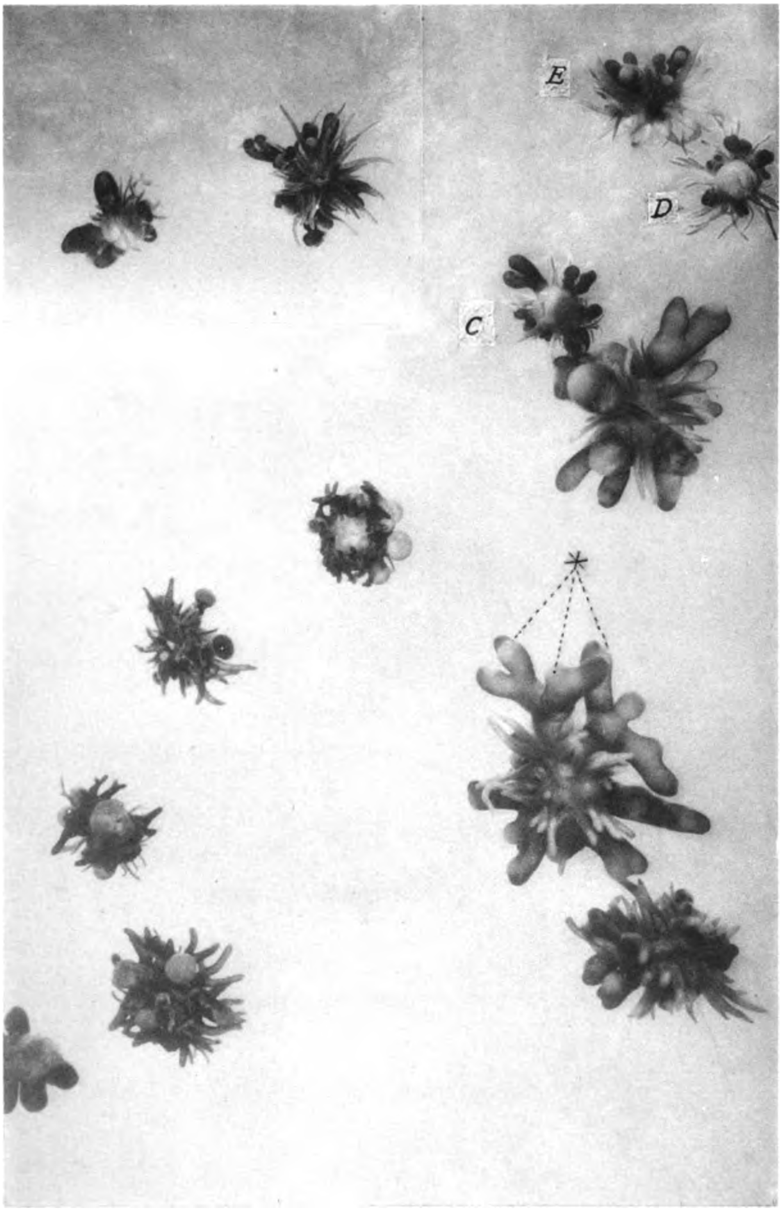
The specimens seem to have the capacity to move about more or less freely, and it seemed to me these organs might aid in such movement; but McClendon is of the opinion that the tentacles are used for this purpose. It will be observed that several of the figures of the plate show specimens inverted, that is, adhering to the bottom of the aquarium by the oral end, the pedal disk being uppermost at the time the photograph was made. It may be stated that the photograph was taken of a series of specimens just as they happened to be disposed in the dish, and shows in a very striking way the remarkably variable character of the creatures.

Color pale olivaceous-green to brownish; tentacles somewhat lighter; foliose organs darker, even brownish, with flake-white pads, sometimes with a darker center, and with whitish lines extending along the upper side, especially in the region of the pads and towards the tips.

The body seems to be rather highly contractile, but there is only a weak or diffused sphincter, and none of the specimens showed any considerable contraction of the oral disk, or the retraction of the tentacles. The mesenteries are numerous, apparently hexamerously arranged.

The reproductive season seems to be in the spring and early summer. Early development takes place within the enteron of the parent, ciliated embryos being found rather commonly in the capacious cavities of the fronds, as well as in the gastric spaces among the mesenteries. Free swimming planulæ finally emerge and after a period of freedom settle down by attaching themselves after the usual method of planulæ. The first organ to appear is as usual the mouth, followed by the tentacles. The foliar organs would seem to appear rather late in the history of development, none having yet appeared in embryos reared in the aquaria.

The habitat seems to be chiefly in holes, crevices, or similar secluded places in the coral reefs or about the shoals where suitable conditions are afforded for their protection. In these places they expand and extend the tentacles and fronds beyond the opening, and in this attitude fish for appropriate prey. McClendon has expressed the opinion that the fronds may serve as lures for attracting prey. This may be extremely doubtful. I am disposed to regard them rather as organs which may aid in capturing and holding prey. The bifurcated tips armed with glandular pads bristling with nematocysts would seem to point to some such function as that herein suggested.



Photograph from live specimens in various aspects of posture, expansion, etc. C, D, and E show specimens in inverted position; the last seen from the side. At * are shown pads of nematocysts on tips of fronds.

V.

ON ADAPTATIONS IN STRUCTURE AND HABITS OF SOME MARINE ANIMALS OF TORTUGAS, FLORIDA.

BY J. F. MCCLENDON,
Instructor in Histology, Cornell University Medical College, New York City.

2 plates, 1 text figure.

ON ADAPTATIONS IN STRUCTURE AND HABITS OF SOME MARINE ANIMALS OF TORTUGAS, FLORIDA.

By J. F. McClendon.

In June, 1908, at the laboratory of the Carnegie Institution of Washington, at Tortugas, Florida, I began the study of the habits of some reef animals with a view to some comparative studies of behavior. The results were written up in the Zoological Laboratory of the University of Missouri.

It was found that many of these animals were thigmotatic and remained in glass tubes rather than in the open. They also learned to find the tubes when removed from them. Such was the case with five species of the Alpheidæ, one of the Pontoniidæ, *Typton tortugæ* Rathbun, and *Gonodactylus œrstedii.* All the anemones were thigmotactic on their bases. These same animals were heliotropic. The Crustaceans were negatively heliotropic and the anemones kept their bases from the light, while *Cradactis variabilis* Hargitt hid all but the tips of the fronds and tentacles from the light. In removing its base from the light, *Stoichactis helianthus,* which lives on coral heads, makes snail-like movements similar to *Metridium,*[1] while *Cradactis,* which lives in holes in decayed coral heads, crawls on its tentacles.

ON ADAPTATIONS OF SYNALPHEUS BROOKSI AND TYPTON TORTUGÆ.

In lagoons between the reefs is found the loggerhead sponge, *Hircinia acuta,* which grows to 3 feet or more in diameter, but is of no commercial value. The passages in this sponge are thickly populated by *Synalpheus brooksi* Coutière. These Alpheids are thigmotactic and negatively heliotropic and seldom come outside the sponge, which they do only at night and then rarely leave its surface. The only other animals seen in the interior of the sponge were a small species of Amphipod and a Pontoniid. The Alpheids were several hundred times as numerous as the Amphipods or Pontoniids. Near or at the surface crabs and worms were sometimes found.

Both Alpheid and the Pontoniid, *Typton tortugæ,* have the fourth and fifth pairs of thoracic appendages pincer-like (plate 1, figs. 1 and 3). In the Alpheid the fourth and in the Pontoniid the fifth pair are asymmetrically hypertrophied. In the Alpheid the asymmetry is very great, and the large chela can be snapped with such vigor as to produce a loud, clicking sound. When this claw is removed its mate grows to replace it and the asymmetry is reversed, as first shown by Przibram. It is not known on which side the large claw develops first. I interpret Herrick's records as demonstrating that the large claw develops first on the left side in *Synalpheus minus* (*Alpheus saulcyi*).[1] It was found in my specimens about as frequently on the right as left side in both large and small individuals. Of 50 taken at random, 22 had the large claw on the left and 28 on the right. In another species Przibram found 40 individuals with the large claw on the left and 47 on the right.

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[1] McClendon, 1906, On the Locomotion of a Sea Anemone, Biol. Bull. 10.

The Pontoniid *Typton tortugæ*, as was stated above, has the pincer-like appendages of the fifth thoracic segment well developed. One of these claws is much larger than the other, but the asymmetry is not as great as in the Alpheids. Both of these claws are snapped with a sharp, clicking sound. When the large claw is removed the small one grows to take its place, as in the Alpheids.

The two animals do not perhaps resemble one another as much in general coloration as in general form, though the color varies so much in both animals that these differences are not at first noticeable. The color darkens with age. The Alpheid varies from the color shown in plate 1, fig. 1, to a light brown. Specimens with a claw like fig. 2 may be a dull cream or light brown in general color. The nerve cord and some other organs may be surrounded by red pigment cells. Yellowish, brownish, or reddish glands in thorax or abdomen may show through.

The Pontoniid *Typton tortugæ* varies from the color shown in fig. 3 to an almost colorless condition, or to a light red or a pale bluish. The large claw of the pale specimens is often paler than the small claw in fig. 3. After the large claw has been removed the small one grows to take its place, but for some time retains more or less its general form and color. Often yellow, brown, or green glands show through in the thorax and abdomen.

As these animals pass their entire adult existence in the dark or dim light, it is improbable that their color is of much significance in their struggle for existence; hence it would not be fixed by natural selection. The fact that their eyes are not degenerate might indicate that they sometimes come near the mouths of the passages in the sponge. Perhaps they are forced out when the sponge becomes overcrowded, but I doubt that many of the larger ones would find another sponge before they were eaten by fish. Neither form was found in any other habitat, though Herrick records the Alpheid from reef rocks as well as loggerhead sponges in the Bahamas.

The Alpheid has large eggs, few in number, attached to the swimmerets of the female. The metamorphosis is abbreviated, and in some cases omitted. The young remain attached for a time to the mother, but perhaps always leave the sponge and live a short pelagic life before finding another sponge. The female Pontoniid deposits numerous small eggs on the swimmerets. These hatch into small larvæ which lead a comparatively long pelagic life before acquiring the form and habits of the adult.

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[1] Brooks and Herrick: The Embryology and Metamorphosis of the Macroura. Mem. Nat'l Acad. Sci., 5, 1891.

I studied the habits of these animals as well as I could in dim light in the cavities of pieces cut from the sponge. They appeared to behave normally, whereas in glass tubes in brighter light they remained motionless. Both animals explore the cavities of the sponge with cautious movements unless disturbed, in which case they snap their claws. The Alpheid advances, using its large claw as an antenna and protector. Its antennæ can be extended about as far forward as the large claw. When meeting an Alpheid or a Pontoniid it may try to squeeze past or it may snap its claw. When placed in glass dishes Alpheids cut one another to pieces, but this is seldom if ever done in the narrow passages of the sponge.

The Pontoniid *Typton tortugæ* advances, using both claws as antennæ, the antennæ being very much shorter than the smaller claw. It spreads the claws apart and waves them about, thus exploring the cavity in front of it. On meeting another it behaves as the Alpheid, except that it may snap either or both claws. Both animals try to squeeze through small openings. The chelæ of *Typton* sometimes show what appear to be claw marks. As their claws are more slender, hence more easily grasped and less powerful than those of the Alpheids, it is to be expected that they would show claw marks first in case both species snapped with equal frequency.

Both animals appeared to eat from the walls of the cavities in the sponge, but I did not determine whether they ate the sponge itself or a sediment deposited on it. I did not determine whether they ate one another in the sponge, but they were so numerous that it seems strange that they received sufficient oxygen. The Alpheids are sometimes infested with a parasitic isopod, *Bopyrus*, in the gill cavity.

I do not intend to discuss here the origin of the form or habits of these animals, but it seems to me that we have here a convergence both in form and habit. It is probable that similarity in form and habits made both animals better suited to living in the same habitat, *i.e.*, the sponge, and that accidentally finding the sponge they remained there. However, this does not explain why the young at the end of pelagic life always (or at least usually) select the loggerhead sponge. There are numerous Alpheids living in holes in the reef rocks, and certainly they are more closely related in form and general habits to *Synalpheus brooksi* than is *Typton*.

This *Synalpheus* and the *Typton* select the sponge not because it has holes in it in which they can hide, but on account of some more specific quality, such as taste (smell), color, or outward form. Or when some individuals of these species have established themselves in a sponge the others may be attracted to it by a social instinct (which may not be disproved by the fact that they destroy one another when placed under unnatural conditions). The isolation of these animals in the loggerhead sponge is an example of what Gulick calls habitudinal segregation and may have been a factor in the evolution of the species.

Since the Alpheids occur in far greater numbers than *Typton* we might suppose the former to be much better adapted to living in the sponge than the latter. However, although *Typton* produces more eggs, it has a much longer pelagic life than the Alpheid and is much more likely to be eaten or swept out to sea by the tides, where it can not find a sponge when the proper time comes.

The smallest loggerhead sponges I found would not live in a large aquarium with running sea-water more than 2 days before the water began to get foul within the passages in the sponge and the Alpheids and *Typton* began to die. Field observations were very limited. These and other difficulties restricted the investigation to its present limits.

ON ADAPTATIONS OF THE REEF ANEMONE, CRADACTIS VARIABILIS.

Cradactis variabilis Hargitt is an anemone about an inch or two in length when expanded, living in holes in old coral heads or reef rocks. Besides the tentacles, which are few in number and arranged as in *Sagartia*, long outgrowths called fronds extend from the region bearing the tentacles (plate 1, figs. 4, 5; plate 2, figs. 8, 9, 10). The animals may be a moss-green or brown in general color, but the tentacles are always paler and often colorless and transparent at their tips. The fronds may or may not be branched, and may end simply or in pale knobs, as in plate 1, fig. 4, or in curious "eyes," as in fig. 5.

These anemones are usually found in cavities in old coral heads that communicate with the exterior by a number of passages about half an inch or more in diameter. The anemones are attached near enough to these passages to extend the tips of the fronds to the exterior (plate 2, fig. 7). This extension is caused by heliotropism of the fronds. One mistakes them at first for sea-weed, although they do not resemble any particular kind of sea-weed that I have found growing on the reefs. The tentacles are extended about as far as and sometimes a little farther than the fronds, but the fronds tend to conceal the tentacles. At night the fronds are contracted and the tentacles remain extended; therefore it is probable that the fronds are not necessary as breathing organs.

If a bit of crab meat is held near the passage through which the *Cradactis* is extended no response is obtained. But if one of the fronds is touched with the meat the tentacles are extended toward it, while the frond touched may contract slightly. In order to observe the food-taking more minutely, some of the anemones were taken from the rock and allowed to attach themselves to the bottom of an opaque dish filled with sea-water. When a bit of crab meat is placed on the end of a tentacle it adheres and the tentacle and one or more adjacent ones are bent down and the food placed on the mouth and pressed there. Immediately many or all of the tentacles are pressed on the food, hiding it from view until it is swallowed. The fronds may contract more or less during the process. *Cradactis* sometimes swallows filter paper placed firmly on the mid-region of a tentacle or on the disk, but not when placed on the end of a tentacle. This may be a question of degree or extent of stimulation. It disgorges the paper within 10 minutes. It rejects bits of shell, etc., placed on the disk or tentacles.

India ink placed in the water near the anemone showed ciliary currents running towards the tips of the tentacles and fronds, and on the disk running towards the mouth. A secretion sticks the particles together. These currents are useful on both fronds and tentacles in the rejection of particles, and on the tentacles in the placing of food in the mouth, the food being carried to the tip of the tentacle before it is placed in the mouth.

When disturbed by light falling on the base, it sometimes moves with snail-like motion (like *Metridium*) a short distance, but the tentacles catch hold of the substratum on all sides. The tentacles and column sometimes perform writhing movements. More often the animal bends over to one side and catches hold of the substratum with the tentacles, with or without previously elongating the column, the fronds contracting slowly all the while. It then loosens the base, walks on its tentacles to a new place (plate 2, figs. 11, 12), bends over and attaches the base, and lets go its hold with the tentacles. This method of locomotion is much more rapid than that of *Metridium*, but could not be used if the *Cradactis* did not live in holes, as it might otherwise be washed away by the currents that constantly sweep over the reefs.

The resemblance of the fronds to sea-weed leads one to suppose that they act as lures or in hiding the *Cradactis* from its prey (anemones being unpalatable are usually not in need of protection). The fact that the fronds are heliotropic and contracted completely at night is in harmony with this view. I did not cut them off to see whether the anemone would live and reproduce as well without them. The cavities containing the *Cradactis* are inhabited by other animals, especially a small black crab, and one might suppose that the fronds protected the tentacles of the anemone from the legs of the crabs that crawled over it. The crabs are active at night in the least light in which they can be seen (their black color making them hard to see in the holes in the rock). In case they are normally active at night the fronds would serve as a protection from the crabs only half of the time. The anemones sometimes grasp the crabs and hold them until they wrench themselves loose, which they invariably do in a short time. Perhaps the anemone gets part of its food as particles dropped from the crabs' mouths.

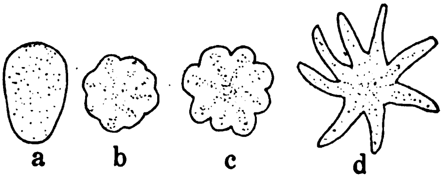


FIG. 1.—*Cradactis variabilis*. *a*, Planula just escaped from cœlentric cavity of mother, oral (pigmented) side uppermost. *b*, The same, second day, seen from oral side; pigment arranged radially. *c*, The same, third day. *d*, The same, fourth day; tentacles elongating and septa becoming distinct. The mouth should be elongated in the plane of symmetry.

Cradactis develops to the planula stage in the cœlenteron of the mother. On being released, the planula swims around for a few hours (text fig. 1, *a*) and attaches itself (*b*) by the smaller end. It gradually develops a mouth and tentacles (*b-d*). When first liberated, the planula has 8 mesenteries, and 8 tentacles develop soon after. Individuals were seen with 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28 and more tentacles. From this one might conclude that the tentacles (and mesenteries) appear in pairs, but they were often observed to appear in sets of four, symmetrical in relation to the oral plane. The first pair of fronds appear in the 20-tentacle stage as outgrowths of the body-wall just beneath the tentacles and with their axis perpendicular to the oral plane. The second pair of fronds appear in the 28-tentacle stage or later.

SUMMARY.

(1) Convergence in structure and habitat is the cause of commensalism between an Alpheid and a Pontoniid living in the loggerhead sponge.

(2) Abbreviation of its pelagic life accounts for the numerical supersedence of the Alpheid.

(3) The weed-like outgrowths or fronds of a reef anemone, *Cradactis*, probably hide it from its prey.

(4) *Cradactis* is kept just within the mouths of cavities in reef rocks by the combined action of negative heliotropism of its base and positive heliotropism of the fronds. The fronds are entirely contracted in the absence of light.

(5) The fronds possess the sense of taste but do not carry food to the mouth.

(6) *Cradactis* moves from place to place by walking on its tentacles, a phenomenon sometimes seen in *Hydra*.

DESCRIPTION OF PLATES.

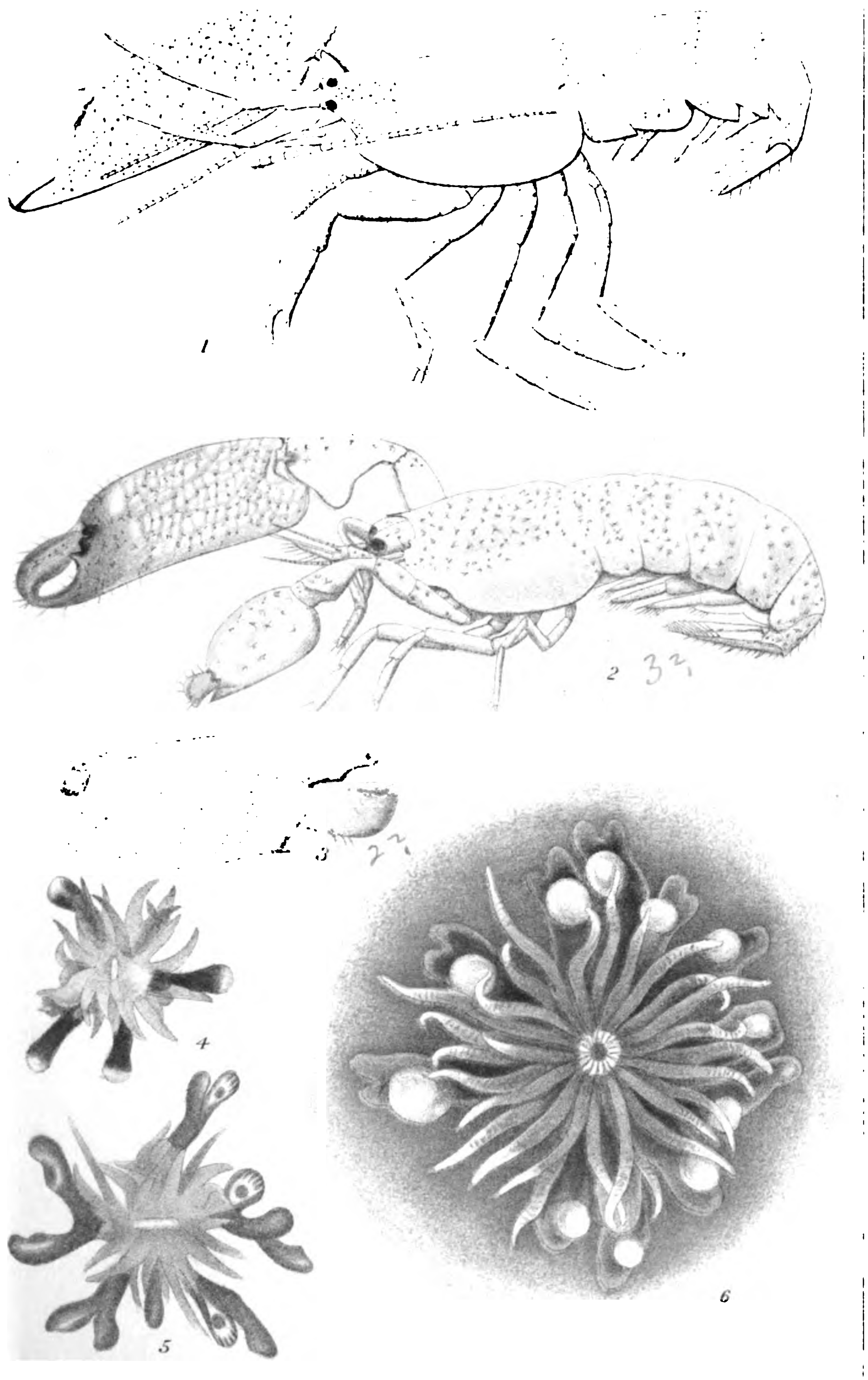
(Figures 4 and 5 were redrawn by Mr. Kline, fig. 6, from life, by K. Morita, otherwise the drawings and photographs are the author's.)

PLATE 1.

1. *Synalpheus brooksi* Coutière.
2. Chela of same species to show different coloration.
3. *Typton tortugæ* Rathbun commensal with the above.
4. *Cradactis variabilis* Hargitt.
5. The same, showing another variety in color and shape of fronds.
6. *Cradactis variabilis* Hargitt, × 2.

PLATE 2.

7. A portion of an old coral head showing the fronds (f) of *Cradactis* protruding from the cavities.
8–10. *Cradactis variabilis*, showing varieties in shape of fronds.
11, 12. *Cradactis variabilis*, walking on its tentacles, with detached base toward the observer.



1. **Synalpheus brooksi Coutière.**
2. **Chela of same species to show different colorations.**
3. **The Pontoniid commensal with the above.**
4. **Cradactis variabilis Hargitt.**
5. **Cradactis variabilis Hargitt.**
6. **The same, showing a third variation.**

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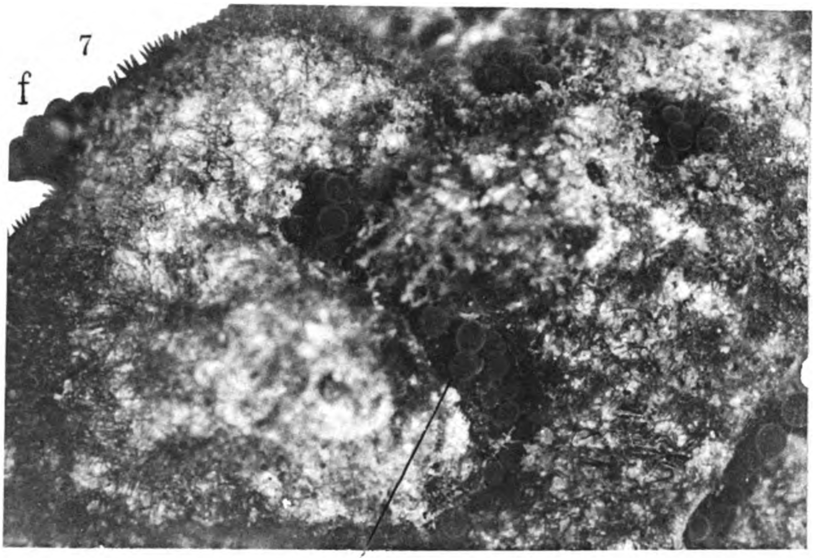

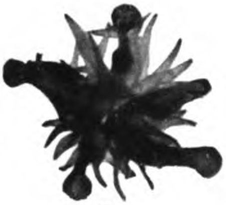
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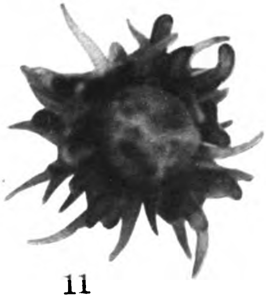
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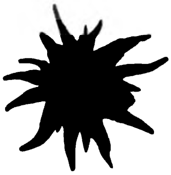
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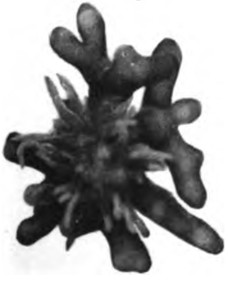

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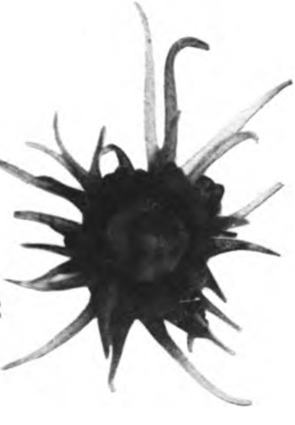

Fig. 7. A portion of an old coral head showing fronds (f) of Cradactis protruding from the cavities.

Figs. 8-10. Cradactis variabilis showing varieties in shape of fronds.

Figs. 11-12. Cradactis variabilis walking on its tentacles with detached base toward the observer.

VI.

BEHAVIOR OF THE LOGGERHEAD TURTLE IN DEPOSITING ITS EGGS.

BY S. O. MAST,
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BEHAVIOR OF THE LOGGERHEAD TURTLE IN DEPOSITING ITS EGGS.

BY S. O. MAST.

The loggerhead turtle ordinarily comes out of the sea in the early part of the night and lays its eggs in the sand on the beach above high-tide water-mark. On July 11, 1910, I was fortunate enough to be present when a turtle came out to lay on Loggerhead Key, Florida, while it was still daylight (7^h5^m p. m.). This individual was about 3 feet long and 2 feet wide. She came out at right angles to the water line and proceeded directly up the beach 50 to 60 feet, where she immediately began to make her nest. There was no indication whatever of a process of selection of the place for the nest, as some have asserted in describing the breeding habits of this turtle. When the turtle reached the nesting-place she stopped and began at once to move the posterior end from side to side, throwing the sand out sidewise and forward alternately, with the two hind flippers, to a distance of 5 to 6 feet. Thus a crescent-shaped trench was made, wide and deep in the middle and narrow and shallow at either end. This trench was over 4 feet long and nearly 10 inches deep in the middle. The lateral movement of the turtle during this process of digging was largely due to the action of the muscles connected with the front flippers, which remained stationary as the body turned on them.

After the trench was finished the turtle took a position so that the right hind leg was very nearly over the middle of the bottom of it. This flipper was then thrust vertically down into the sand (the flat surface being nearly parallel with the long axis of the body) and the end turned in under the sand so as to form a cup much like one formed by a human hand partly closed. The posterior end of the animal was then raised by the action of the left leg and pushed to the right. During this process the right flipper, containing a fair-sized handful of sand, was of course raised and as the posterior end of the body moved to the right the flipper gradually rotated so as to face backward; it was then thrust out to the side and inverted so as to empty the sand in a heap, just in front of which the foot was placed on the ground in the customary position. The left flipper was now directly over the hole made by the right one and used in removing sand just as described, except that it took the sand from the right side of the hole while the right flipper took it from the left side. Before the body was pushed back to the left by the right leg it made a sudden movement forward and threw out a considerable bit of sand, making a hole just in front of the place where the sand taken from the nest had been deposited. This sand was pushed into the hole in front of it when the turtle moved back to the right again and thrown out just before it moved to the left the following time. Thus the two hind flippers alternated in scooping the sand from the nest until a cylindrical hole was dug nearly as deep as their length. The alternation from right to left was perfectly regular. Neither flipper ever took sand from the hole twice in succession.

After the hole was completed the turtle assumed a position so that the cloaca was very nearly over the center of it and began to lay at once. The cloaca projected fully 2 inches during the process of laying. The head was well extended and flat on the ground. The anterior end of the body was raised so that the ventral surface made an angle of about 20° with the horizontal. There was no arrangement of the eggs in the nest as fishermen sometimes assert. The eggs were dropped from the cloaca into the hole in a series of one or two at a time at intervals of from 4 to 8 seconds. Two were deposited together about every fourth time. During the discharge of the eggs the hind flippers were slightly raised, and in one case (witnessed at night earlier in the summer) there was heavy breathing which was very distinctly heard. In the turtle under present consideration, however, not the slightest sound was detected.

Fishermen often say that after a turtle begins to lay it will continue even if it is turned on its back. I did not try this, but I did strike the turtle a sound blow on the head with a heavy stick, using both hands, at two different times while she was laying. She withdrew her head, moved slightly to one side and stopped laying, but only for a few moments. Noise and gentle contact did not appear to affect her in the least.

It is commonly thought that the loggerhead turtle ordinarily lays three times during each summer, about 150 eggs the first time, fewer the second time, and about 80 the third. I did not ascertain precisely how many eggs were laid by the turtle under observation. It is almost impossible to remove the eggs from the nest without killing the embryos, and, since there have been many trustworthy observations on the number of eggs laid, it seemed unnecessary to destroy the young for the sake of learning the exact number in this particular nest.

Immediately after the eggs were discharged the turtle began to cover them. In doing this she moved the posterior end back and forth much as she did in digging the hole. As this end proceeded to the right the left flipper was thrust backward into the sand and then suddenly moved inward so as to throw and scrape the sand on to the eggs immediately back of it. As it proceeded to the left the right flipper acted in the same way, but of course it threw the sand in the opposite direction. Thus the turtle filled the trench as well as the hole, stopping frequently to pack the sand, especially that over the eggs. This she did by placing the posterior pointed end of the body on the sand and elevating the anterior end so as to bring her full weight to bear upon it. After the trench was nearly filled she turned about over the region several times and threw and scattered the sand in every direction with all four flippers so as to conceal the place, especially that where the eggs were laid. This completed she returned to the sea and entered only a few feet from the spot where she came out. On the way down the beach I stood on her back and she carried me (165 lbs.) apparently with but little effort. From what has been said regarding the concealment of the nest of the loggerhead turtle it must not be assumed that the nesting-place is difficult to find—quite the contrary, for the turtle-tracks leading to and from it are very conspicuous and can not be mistaken. The place where the eggs are buried is, however, not easy to find. In case of the nest described I had considerable difficulty in finding the eggs, even after carefully watching the whole process of laying and noting the position of the turtle in detail; and this is quite in harmony with the experience related to me by several fishermen who collect the eggs for food.

The eggs in this nest were 11 inches below the surface, and they occupied a space 6.5 inches in depth and 9 inches in diameter, making the bottom of the nest 17.5 inches from the surface. The turtle under observation was out of water 42 minutes, approximately 3 of which were required to come from the water to the nest, 4 to make the trench, 8 to dig the hole, 12 to lay the eggs, and 15 to fill the hole and trench, smooth off the place and get back to the sea. The rate of locomotion on land is about half a mile an hour.

VII.

CERTAIN REACTIONS TO COLOR IN THE YOUNG LOGGERHEAD TURTLE.

By DAVENPORT HOOKER,
Of Yale University.

2 plates, 1 text figure.

CERTAIN REACTIONS TO COLOR IN THE YOUNG LOGGERHEAD TURTLE.

By Davenport Hooker.

During the summer of 1907 I made some observations of a very preliminary and incomplete nature on the general habits and early instincts of the young loggerhead turtle. A series of experiments was performed with a view to determining the cause of the newly hatched turtles reaching the water and the results obtained led me, at the time, to believe that photophilism and negative geotropism were the elements at work. In the summer of 1908 I repeated my experiments in a much more thorough manner and extended the research greatly. From the newer and more complete data obtained, I am convinced that I overlooked certain very important factors in the environment and that reactions to color and geotropism are the determining factors. I therefore take this occasion to correct what was said last year about phototrophism as such an all-important factor, though it certainly does play some part, as my more detailed account will show.

An idea of the locale of the experiments may be obtained from fig. 1. Pit *A* is on the northwest side of the island, some 30 feet from the water's edge, and is overhung on the more easterly side by bay-cedar bushes. Pit *B*, on the center of the point, is 10 feet in diameter and about 4 feet deep, with sloping sides and the floor entirely out of sight of any bushes or the ocean. The floor and walls are of sand. The shore of the island is of coarse coral sand and free of vegetation. The deeply shaded area shows where the bay-cedar bushes extend along the central ridge of the island.

The material used was afforded by three nests totaling about 300 turtles. These nests were surrounded by a high wooden pen which prevented the escape of the young turtles and also prevented them from seeing the ocean, the bushes, and the directive rays of the sun. The young turtles were used as soon as possible after they had reached the surface of the ground. In no case was the interval over 10 hours, while in some instances they were helped out of the sand by gently raking it with the fingers. There was absolutely no noticeable difference in the response of the turtles kept 10 hours from those used immediately.

EXPERIMENTS.

When I was working on the young turtles in 1907, all my experiments were performed in Pit *A*, and in the evening. At that time the sun was in the west and the turtles all went west without exception. As they were distinctly photophilous when swimming in the aquarium, I very carelessly neglected the overhanging bushes on the eastern side of the pit and seized upon their apparent tendency to go toward the light as the cause of their movements. On thinking the results over during the following winter, however, it seemed improbable that the sun's rays should be the governing factor in the young turtles reaching the sea, for what would happen if they were hatched on the eastern side of the island when the sun was in the west? It was with the purpose of finding the explanation to this question that the work was again undertaken in 1908, in a much more thorough manner. I found that if several young turtles were tried in Pit *A* when the sun was in the east, they still went west. Obviously, then, they were not responding to the sun in this case. Was it possible that the green bushes were the determining factor? If they went away from the bushes on the western side of the island irrespective of whether the sun was in the east or in the west, they should do so on the eastern side. Consequently, four turtles were given four trials each, under the following conditions: Sun to the west, bushes on the west within 8 feet of the place chosen for the experiment (fig. 1, E), which was a small, level place on the beach with a semicircular barrier of sand just high enough to shut out sight of the ocean about 15 feet to the east. The turtles were tried, one at a time, by being set down on the land side (west) of the barrier, headed successively to west, north, south, and east. In every case, the turtles crossed the barrier directly towards the sea.

The results show conclusively that the position of the sun had nothing to do with the response, but the question arose as to whether or not the odor of the ocean or the sound of its waves might not have been influencing factors. To obviate this I selected a spot as nearly in the center of the island as possible, about an eighth of a mile from either shore, where there was a natural semicircle of bushes inclosing a white, sandy space with a definite opening into a lane, also paved with white sand, on one side. At varying times of the day turtles were, one by one, placed in this inclosure, headed away from the opening, and in all cases (the operator, of course, being entirely out of sight) they came through the opening into the space beyond with little or no hesitation.

These experiments were further supplemented by placing green glass on one side of Pit *B* and a number of turtles tried there, one by one. In all cases they definitely and decidedly turned away from the glass and climbed out of the pit on the opposite side, while in the control experiments, where the turtles were placed in the pit when there was nothing but its sandy walls for an environment, they crawled out at random and went in no definite direction.

Under ordinary circumstances the young turtles are negatively geotropic, but if the possible descents have been exhausted, they become positively geotropic. As the green bushes apparently drove them down hill to the water, a series of experiments was performed to see if their negative geotropism and any stimuli (if there were such) received through the senses of smell and hearing from the ocean could be overcome by their avoiding reaction to the green bushes. The series of experiments may be divided into three parts, *A*, *B*, and *C*, with the following conditions for each:

Series A.—East side of island (fig. 1, c), bushes cut from the interior of the island were stuck into the sand in an upright position to form a semicircle with a diameter of about 5 feet. The water line was tangent to the mid-point of the arc's circumference, about 2 inches from it. A sand barrier, 6 to 8 inches high, was erected just inside the bushes to prevent immediate sight of the ocean. There was a fairly heavy surf and the sun was in the west.

Series B.—The same conditions prevailed as for series *A*, except that the sun was in the east.

Series C.—West side of island (fig. 1, d). The conditions of series *A* were duplicated. The sun was in the east.

Twenty-four turtles were used in these three series, each one given four trials, headed successively north, west, south, and east. Without exception or even hesitation, all turned away from the bushes and went up an incline of 30° away from the water. Their negative response was continued long after the ocean was in sight, but all the turtles, after going from 8 to 10 feet directly up the slope, made a wide detour and started for the ocean, giving the bushes a wide berth. The position of the operator was an entirely negligible quantity so long as he remained perfectly quiet.

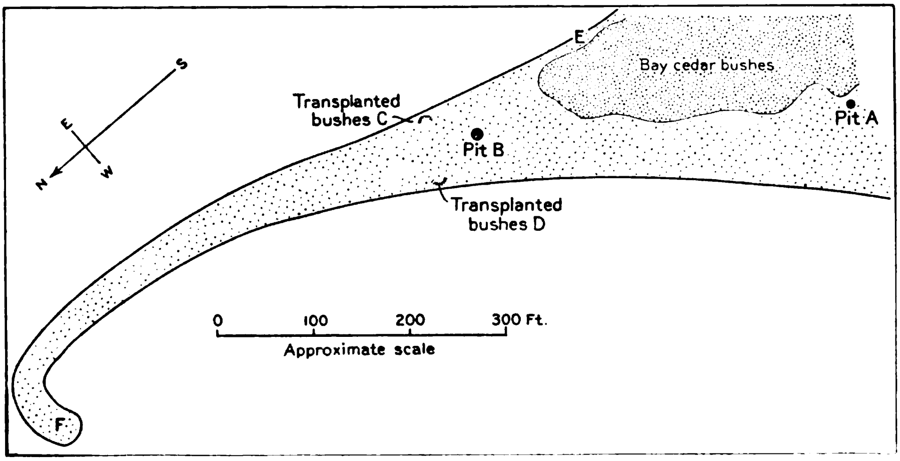

Fig. 1.—Northern end of Loggerhead Key, Tortugas.

The next series of experiments was performed in location fig. 1, c. The bushes were removed, and the barrier moved back so that it was washed by the waves. A piece of colored glass, 2 feet 6 inches long by 18 inches high, was forced into the sand in an opening in the middle of the barrier in such a manner that the sandy floor inside was on a level with the water outside and separated from it only by the glass. The barrier around the ends of the glass and up the slope of the shore for a few feet kept the water out of the semicircular inclosure. The young turtles could see the ocean and the surf through the glass, but it was, of course, a colored ocean when thus viewed. The other conditions were the same as for series *A* in the experiment with the transplanted bushes. Three glasses were used, differing in color, green, orange-red, and blue. They were tried in the order named. Five turtles were tried in each experiment, each one giving four trials, facing in turn north, west, east, and south. Although they could see a green ocean perfectly well when the green glass was used, their avoiding reaction to green took them up the bank and away from the water in every instance. When the orange-red glass was used, there was a similar avoiding response, but when the blue glass was used, all the individuals in all their trials were strongly attracted to it. I had no red glass, so a red sheet of cardboard was used instead. To this they all responded with the avoiding reaction.

A series of experiments was made in Pit *B* by setting up blue glass or blue cardboard on one side and another colored glass or cardboard (red, green, or orange) opposite, and placing the turtles between the two. In every case they went to the blue. Controls with blue alone showed the same result, while a negative response was always obtained when blue was absent and one of the other colors present.

A series of experiments was tried at night with 9 turtles on the northern end of the key just beyond Pit *B*. It was a bright, moonlight night and the bushes and other objects on the point, as well as the sea on the east and west, were plainly visible. The turtles were placed one at a time at about 6 feet north of Pit *B*. The operator retired as far as possible, still keeping the subject in sight, and the turtle was allowed to go at will. All the turtles turned north at first until they reached a point on the central ridge of the sandspit from which the ocean was visible in either direction. Then the course was changed toward the west in 5 cases and toward the east in 4. The route to the water was not a direct one, but was either northwest or northeast, the point of entering the water varying from 75 feet (in one case) to 250 feet from the starting-point. The position of the operator was again an entirely negligible quantity. This series of experiments is of particular interest, as it seems to be a combination of or a transition reaction between the response to colors and the purely photophilous response which they do give.

All of these experiments recorded above were performed in the open air, under surroundings as nearly natural as possible. In addition to these, certain experiments were performed under a rigidly restricted environment to test their phototropic response.

Dr. L. J. Cole,[1] of the University of Wisconsin, found that "animals having image-forming eyes and which are positively phototropic, respond to a large area of light of comparatively low intensity rather than to an illuminated point of high intensity." The apparatus which he used was highly complex and entirely beyond the facilities at my disposal. Nevertheless, I made a much cruder and simpler form on essentially the same plan and tested several young loggerheads. While they are very slow in responding under such artificial conditions, their reactions bear out the expectations for a positively phototropic animal. When the light of a lantern is thrown at night into one of the pens containing from 50 to 75 turtles, all orient and crawl toward the lantern and remain in the area lighted by it. When in a large aquarium, all the turtles coming within the area lighted by a lantern remain there and orient toward the light.

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[1] Cole, Leon Jacob, An Experimental Study of the Image-forming Powers of Various Types of Eyes. Proc. Am. Acad. Arts and Sci., vol. XLII, No. 16, 1907.

In 1907, I thought that the young turtles followed the sun in swimming out to sea, but my more recent work has changed my opinion. About 50 young turtles were let loose on the point (fig. 1, F). All went into the sea and swam 100 yards in their initial direction, then paused, turned abruptly toward deep water and swam to it. By placing a simple type of spectroscope in a water-glass and covering my head and the bucket with a dark cloth, I was able to get very satisfactory "reflection spectra," if they may be so called, of the sea-water at different depths. This is a spectrum taken below the surface of the water and at a slight angle below the horizontal. The results obtained were interesting in that the deeper the water the greater the blue content of the light reflected and vice versa. As the turtle swims with its head below the surface of the water, it is quite possible that the greater blueness of the deeper water attracts it.

As a final test of the rôle played by any odor of the ocean water, a glass bowl 18 inches in diameter was sunk to its rim in Pit *B* and filled with sea-water. Turtles were placed one by one on its rim, some of them having been immersed in it before being set down. While some went into the water, many more turned away. They demonstrated no definite tendency to go to it. The turtles behaved in exactly the same manner that they did when there was nothing in the pit. This would seem to indicate that there is no odor in sea-water that attracts the young turtles.

DISCUSSION.

The general results obtained may be summed up as follows:

(1) The newly-hatched loggerhead turtle moves away from transparent and opaque red, orange, and green, and from green bay-cedar bushes, and moves toward transparent or opaque blue.

(2) After entering the water, the animal swims out to sea, apparently attracted by the darker blue of the deeper water. The position of the sun is an entirely negligible quantity.

(3) When on the beach in a large sand-pit with level floor, from which pit sight of the bushes and the ocean is excluded, but into which the sun's rays shine directly, there is exhibited no definite tendency to move in any definite direction.

(4) Young loggerhead turtles are negatively geotropic, but when all possible downward inclines have been exhausted they become positively geotropic.

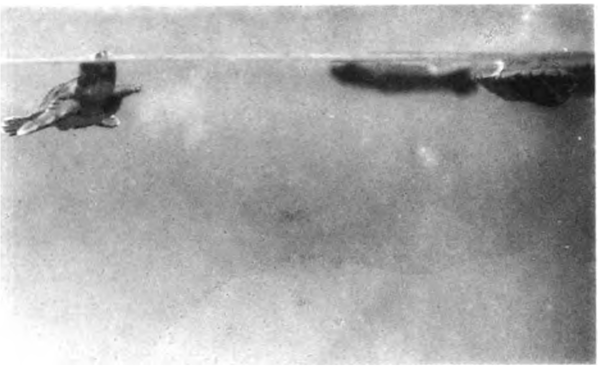
(5) Under a restricted environment the young turtle is photophilous and responds to a large surface of light of low intensity rather than to an illuminated point of high intensity.

(6) The reactions of the young turtle are not modified by sound or odor of the sea, nor by a tank of sea-water in which there is not sufficient quantity to give color.

It might be well to state here that the colors used, both glass and paints, were far from monochromatic, so that their exact values are not known, but at the same time it should be remembered that most or all of the colors in nature are polychromatic. An excess of any particular color seems to give the effect. That we are dealing here with a case of true chromotropism is, perhaps, somewhat doubtful. Indeed, true chromotropism is so rarely met with and so many other factors, as intensity, the "color-blindness" of lower eyes, etc., contribute to it or to startlingly similar reactions, that I have studiously avoided the term. I must also confess myself unable to satisfactorily explain the cause of the response obtained at night on the beach. While the moon shone brightly, the differences in colors were much reduced to the human eye, so much so that, as far as color was concerned, the bushes and the water were practically the same. However, the sea was shiny and the bushes were not. This reaction seems to me to be, as I have before stated, a transitional stage between the color reaction and the photophilous response, but this helps us little in explanation of its ultimate factors.

In regard to the responses in the daytime, we may speak with a little more certainty, although here, too, the intensity of the colors is a bothering element. Practically all the investigators who have worked on color responses have found that blue or the blue end of the spectrum acts as white light and the red end of the spectrum as shadows would in phototropic responses. In the case of these loggerhead turtles we find blue chosen in preference to the directive rays of the sun. Whether this indicates a true chromotropism or not we can not be entirely sure.

The application of the bare facts obtained to their biological significance in the life of the animal is, I think, clear. Bushes, green in color, grow on all islands of any size, above the high-water mark. The shores of all islands slope down to the water. All turtles' nests are laid just above the high-tide mark, at or near the bush line. The young turtle, hatching out and crawling up to the surface of the sand, avoids the bushes, goes down the shore, and easily finds the water. Once in, the darker blue of the deeper water attracts it out of the dangerous fish-infested shoals of the reefs.



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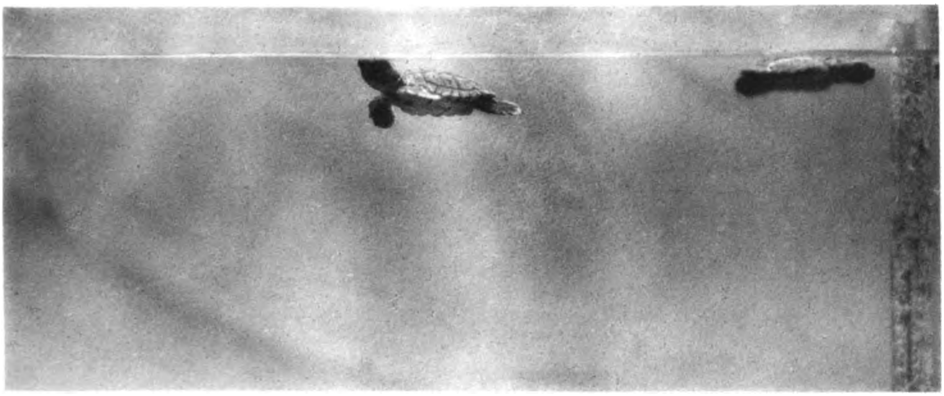

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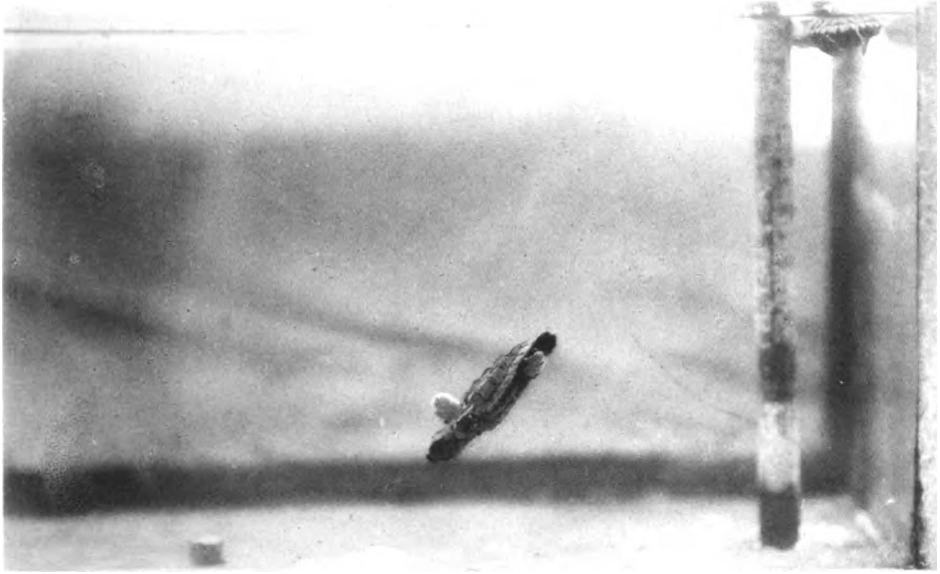

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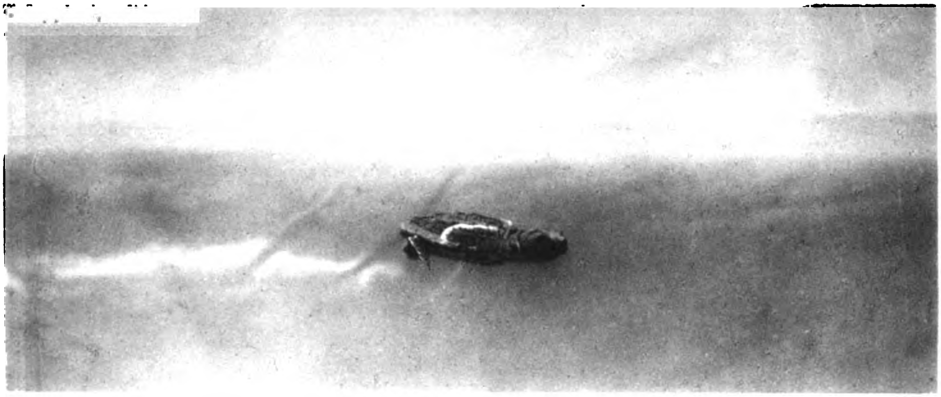
Figs. 1 and 2. Young Loggerheads taking a breath of air. Note the flippers moved to preserve balance.

Fig. 3. Young Loggerhead Swimming.



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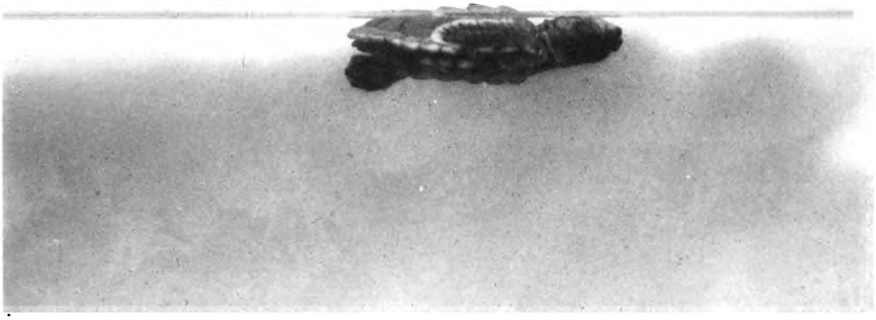

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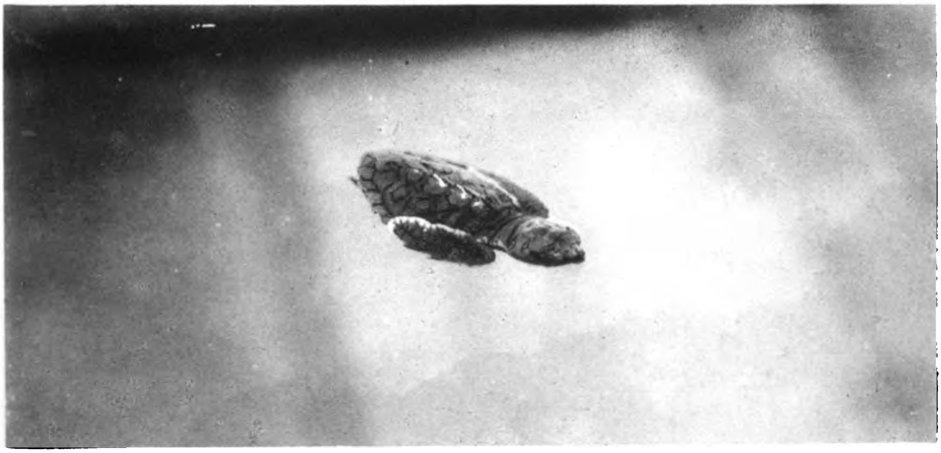

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Fig. 1. Young Loggerhead Swimming.
Fig. 2. Young Loggerhead Floating in the Water (side view).
Fig. 3. Young Loggerhead Floating (from above).

VIII.

A CONTRIBUTION TO THE ANATOMY AND DEVELOPMENT OF THE POSTERIOR LYMPH HEARTS OF THE TURTLES.

BY FRANK A. STROMSTEN,
Assistant Professor of Animal Biology, State University of Iowa.

2 plates, 5 text figures.

A CONTRIBUTION TO THE ANATOMY AND DEVELOPMENT OF THE POSTERIOR LYMPH HEARTS OF THE TURTLES.

By Frank A. Stromsten.

This paper is submitted as a preliminary report of the results obtained by the writer in the study of the lymphatic system of the turtles. While the anatomy of the lymph hearts has been so carefully and accurately described in the sea turtle by Müller (1839) and in the large land turtles by Fritsch (1874), their development, as far as is known to the writer, has never been studied.

Recently, the most general interest has been attached to the development of the lymphatics in general. But the results obtained have been by no means in accord. On the contrary, the most divergent conceptions have arisen through the study of the mammalian type alone. It has therefore seemed to the writer desirable to refer to a more generalized type of vertebrate, in the hope that some key to the divergent results noted might be found. Accordingly, studies have been carried on for several years upon reptilian forms, particularly the *Chelonia*. In the present paper it is proposed to consider only the posterior lymph hearts of the turtle, reserving the fuller treatment of the entire lymphatic system for a later paper.

Several years ago,[1] while investigating the fate of the subcardinal and postcardinal veins in the box turtles, the writer was interested in noting the formation of a pair of rather large, muscular-walled sacs in the subcutaneous mesenchymal tissue of the postiliac regions. These spaces, which proved to be the posterior lymph hearts, seemed to be intimately related in their development with certain changes in the first two or three coccygeal branches of the postcardinal veins. It was not possible at that time to complete the study of these interesting organs. The work was again taken up, however, in the fall of 1908, and has been carried on, as class-room duties permitted, ever since.

METHODS AND MATERIALS.

The work for the most part has been done in the laboratories of animal biology of the State University of Iowa. I wish here to express my thanks to Prof. Gilbert L. Houser, director, and to other members of the Laboratory staff for suggestions and aid in collecting material for the anatomical studies. The embryos of the loggerhead turtle (*Thalassochelys caretta*), used for the study of the development, were collected by the writer during the summer of 1907 at the Marine Laboratory of the Carnegie Institution of Washington at the Dry Tortugas, Florida.

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[1] American Journal of Anatomy, vol. 4, 1905.

It has not been possible to dissect the adult lymphatic system of the loggerhead turtle in time for this preliminary paper. The anatomical description will, therefore, be based on the excellent work of Müller on the green turtle, supplemented by Fritsch's work on the land turtle, and by such dissections as the writer has made on the mud turtles found in the vicinity of Iowa City. The specimens dissected were mostly *Chrysemys marginata*, although specimens of *Chelydra serpentina* and of *Amyda mutica* were also studied. The turtles were killed with chloral hydrate or with chloroform. The blood-vessels were injected with red and with blue gelatin, while the lymphatics were injected with a thin yellow gelatin mass. The melting-point of the gelatin was lowered by adding potassium iodid to the melted solution. The posterior lymph hearts were studied by exposing them after the animal had been chloroformed. As they continue to beat for some time after they have been exposed, they are very easily found and studied. Their connections with adjacent veins can readily be demonstrated by injecting India ink into their cavity.

For the preparation of the embryonic material a large number of fixing agents were used. Corrosive sublimate solutions were, as a rule, not satisfactory, although Zenker's fluid gave fairly good results. Gilson's fluid proved very unsatisfactory, especially with large embryos. The mesenchymal tissues were poorly fixed and the material did not keep well. By far the best results for embryos of all stages were obtained by using mixtures of chromic and acetic acids with pure formaldehyde. These mixtures seem to penetrate the thick shell more readily and to fix the internal organs more thoroughly and with less distortion than any other combination tried. The following mixture for embryos up to about 30 days of development was found satisfactory:

> *Chrom-aceto-Formaldehyde:*[1] Chromic acid, 1 per cent aq. solution, 64 parts; glacial acetic acid, 4 parts; formaldehyde, pure 40 per cent, 32 parts.

The strength of the chromic-acid solution may be varied somewhat to suit conditions. The solution should be allowed to stand until it assumes a greenish or "chrom-alum" color before using. Embryos are fixed from 15 minutes to 6 hours according to size, and washed thoroughly in running water. Although Lee refuses to recognize chromic-formalin fixing agents in the later editions of "The Microtomist's Vade-mecum," the writer is compelled to confess that, after using the mixture mentioned above for a number of years, none of the standard fixing agents have given such uniformly good results as has this one. If the material is not left in the fixing solution entirely too long, and is thoroughly washed out, there is no difficulty whatever in obtaining beautiful stains with any of the standard methods.

Various methods of staining were employed. The most satisfactory results were obtained with Delafield's hæmatoxylin or iron hæmatoxylin followed by slightly acidulated orange G. or eosin-aurantia-orange G.

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[1] Lee "The Microtomist's Vade-mecum." 4th ed., page 55. Norris, Proceedings of the Iowa Academy of Science, vol. 8, page 78 (1900).

Mallory's connective-tissue stain is also very good. Many of the older embryos had the blood-vessels injected with India ink.

Embryos up to 26 days were imbedded in paraffin and cut 10μ to 20μ thick. Older embryos were cut by the celloidin method, about 25μ in thickness and mounted on lantern slides. One series of embryos was cut into 50μ sections, and another series of older stages was cut into sections 100μ in thickness. Wax and blotting paper, as well as graphic reconstructions, were made whenever necessary.

ANATOMY OF THE POSTERIOR LYMPH HEARTS OF TURTLES.

Lymph hearts were discovered in turtles by Joh. Müller in 1839. He describes them in the green turtle (*Chelonia mydas*) as a pair of rounded organs, more or less flattened dorsoventrally, lying just caudad of the upper end of the ilium, one on each side of the body. They rest upon the origin of the semitendinosus muscle of each side and are bordered laterally by the biceps and caudally by the semimembranosus muscles. Lymph channels from the posterior extremities and caudal portion of the body open into their posterior ends. Their pulsations are irregular, occurring at the rate of 3 or 4 times per minute, and are not necessarily synchronous for the two hearts. Their inner wall is smooth and their cavity is free and not broken by trabeculæ or septa, as it is in the land turtle. The openings of the afferent and of the efferent ducts are guarded by valves. They open, by means of a short duct, into the vein that runs forward along their mesial border to become the posterior renal advehent vein of each side.

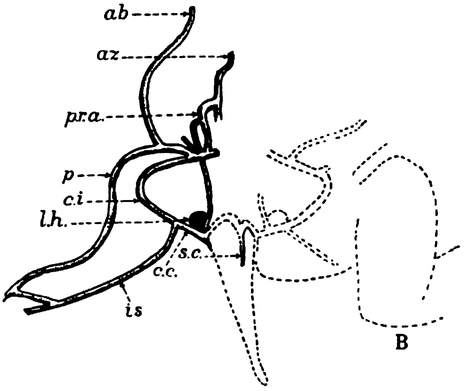

FIG. 1.—Diagram showing relations of posterior lymph hearts to veins of pelvic regions of *Chrysemys marginata*. *ab*, abdominal vein; *az*, azygos; *p.r.a.*, posterior renal advehent; *p*, peroneal; *c.i.*, circumflex iliac; *l.h.*, lymph heart; *is*, ischiadic; *c.c.*, common coccygeal; *s.c.*, superior coccygeal.

In the large land turtle (*Testudo elephantina*), described by Fritsch (1874), the lymph hearts are ovoid in form with a longitudinal diameter of 38 mm. and a width of 20 mm. in the anterior half, and 15 mm. in the posterior half. Their walls contain striated muscle fibers and are about 1 to 2 mm. in thickness. Their central cavity, especially in the posterior region, is broken up by septa and trabeculæ. They open directly into the ischiadic vein, and in the right heart a second opening communicates with a small vein on the inner border of the heart.

In the mud turtle, *Chrysemys marginata*, studied by the writer, the posterior lymph hearts are found just beneath the carapace, immediately caudad of the upper end of the iliac bones. They are somewhat elliptical in form, but are slightly flattened dorsoventrally.

In a specimen about 15 cm. in length, they measure about 6 mm. in length and 4 mm. in breadth in their widest part. They occupy the angle formed by the junction of the common coccygeal with a branch of the posterior renal advehent vein of each side (fig. 1). They do not lie exactly parallel with the long axis of the body, but diverge laterally at their anterior ends. The central cavity is broken up, more or less, into communicating alveoli, especially in the posterior half. The walls are made up of loose connective tissue and striated muscle fibers. The hearts open into a vein connecting the common coccygeal with the posterior renal advehent vein, or sometimes directly into the common coccygeal vein. In the specimens studied, the rate of pulsation, shortly after the animal had been chloroformed, was about four times per minute.

A more detailed description of the anatomy of the lymph hearts, together with their histological structure, is reserved for a later paper on the complete anatomy of the lymphatic system of the loggerhead turtle.

DEVELOPMENT OF THE POSTERIOR LYMPH HEARTS.

The first definite indications of the posterior lymph hearts appear toward the close of the third week of development. But as early as the end of the second week a noticeable vacuolation of the mesenchyme takes place in the region immediately caudad of the anlagen of the posterior limbs, giving it a spongy appearance. About the beginning of the fourteenth day this spongy area becomes invaded by small capillaries from the first three dorsolateral branches of the caudal portion of the postcardinal veins. These minute capillaries can be readily distinguished from the mesenchymal spaces among which they meander, by their endothelial walls. The increased activity of the mesenchyme cells due to the rapid growth of the posterior limbs causes a greater accumulation of lymph in the intercellular spaces, causing them to enlarge and become confluent with each other and, to some extent, with the invading capillaries. The exact relation of the tissue spaces to the capillaries is very difficult to determine. However, after studying a large number of thin sections taken through this region, under the oil-immersion lens, I feel sure that these spaces do open directly into the capillaries.

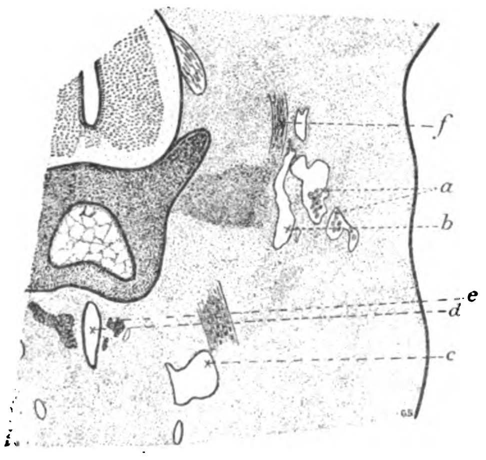

Fig. 2.—Transverse section through lymph heart region of Loggerhead Turtle embryo No. 230. (20 days, 14 mm.) × 100. *a*, veno-lymphatic channels; *b*, vein; *c*, postcardinal vein; *d*, aorta; *e*, sympathetic system; *f*, nerve.

A careful study of such a series of sections can not fail to convince the observer that these spaces play a far greater part in the development of the lymphatics and even of the lymph hearts than is now usually supposed. By the sixteenth day another change takes place which greatly accelerates the development of the lymph hearts. This is brought about by the longitudinal anastomosis of the segmental branches of the postcardinal veins caudad of the opening of the iliac veins and outside of the muscle plates. The veins thus formed continue cranially as the most important branches of the posterior renal advehent veins, and caudally as the lateral coccygeal veins of the tail. The formation of these veins together with the tapping of the mesenchymal spaces allows a much more complete and rapid drainage of the lymph from posterior limbs and tail than was hitherto possible. The capillaries of the region subsequently to be occupied by the lymph hearts increase enormously in size and fuse with each other to form several large, anastomosing spaces, the veno-lymphatic channels. These channels extend parallel with the pair of newly-formed veins mentioned above, and communicate with them at two or three points.

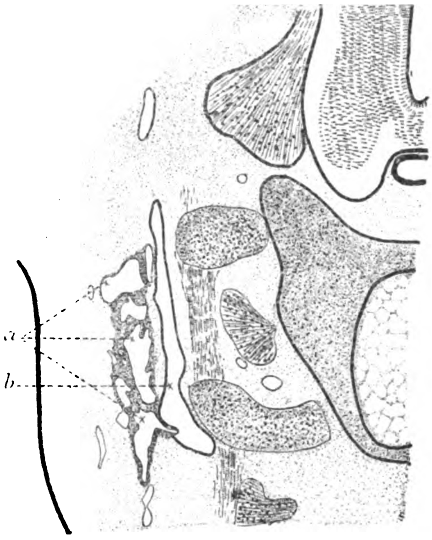

Fig. 3.—Transverse section through lymph heart region of Loggerhead Turtle embryo No. 232. (22 days, 15 mm.) ×100. *a*, veno-lymphatic channels; *b*, vein.

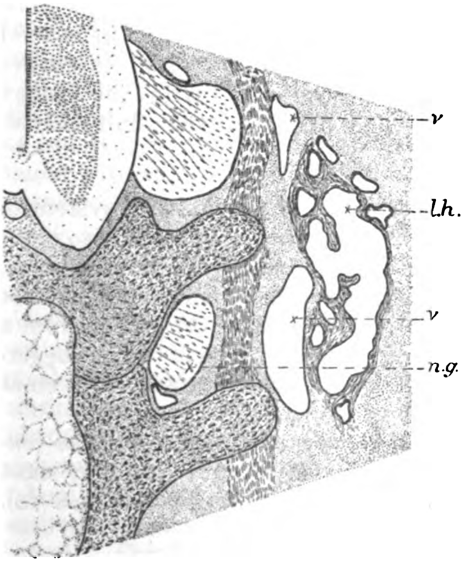

Fig. 4.—Transverse section through left lymph heart of Loggerhead Turtle embryo No. 236. (25 days, 17 mm.) *v*, vein; *l.h.*, lymph heart; *n.g.*, nerve ganglion.

In an embryo 20 days old (fig. 2) the segmental connections between the postcardinals and the recently formed common coccygeal veins are still retained. The anlagen of the lymph hearts are scarcely distinguishable from the veins in this stage. At 21 days of development, the mesenchyme cells begin to condense around these veno-lymphatic channels to form definite walls of considerable thickness and density. Muscle cells also wander in from the adjacent muscle plates and become involved in the formation of these walls. These channels continue to increase in size and complexity through the twenty-second and twenty-third days. Figure 3 represents a section taken through the region of the posterior lymph hearts of an embryo 22 days old. The lower lymph space opens into the vein by a valve-like opening. From the 24-day stage on, the partitions between the several veno-lymphatic channels begin to break away in the anterior part of the heart region, forming fewer and larger spaces. Figure 4, from an embryo of 25 days, shows a section taken through the middle portion of the lymph heart.

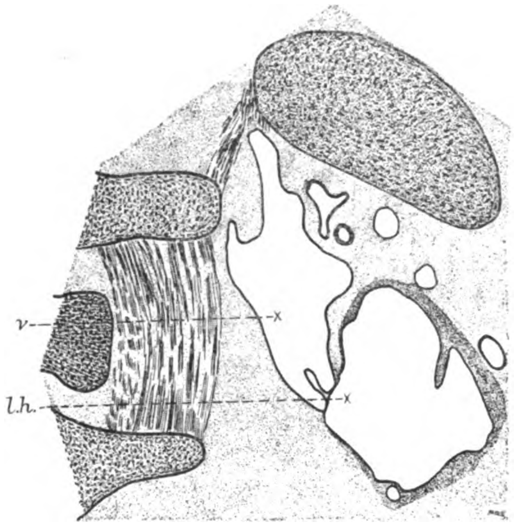

Fig. 5.—Transverse section through left lymph heart of Loggerhead Turtle embryo No. 228. (32 days, 40 mm.) *v*, vein; *l.h.*, lymph heart.

The formation of the lymph hearts is well advanced in embryos of 32 days and older. Figure 5 shows the relation of the lymph heart to the vein and lymph spaces in a 32-day embryo. The process of the atrophy of the walls separating the several lymph heart anlagen continues from before backward until at the time of hatching there seems to be a single cavity present for each heart. In this, as well as in several other points, the development of the lymph hearts of the sea turtles differs from that of fresh-water turtles. In the mud turtles the spongy character of the hearts is retained, to some extent, in the adult animal.

GENERAL CONCLUSIONS.

Recent investigations of the ontogeny of the lymphatic system of mammals have given rise to three general theories. Two of these agree in deriving the lymphatic system entirely from the venous system, while the third assigns to it, in part at least, an independent origin. For purposes of comparison with the results obtained by the writer from a study of the development of the posterior lymph hearts of the loggerhead turtle, a very brief résumé of these several theories will be given at this point.

(1) *The theory of the confluence of independent spaces to form continuous channels.*—This view, which is the one formerly held by most embryologists, is now held in a modified form by Huntington (1908–10). According to this writer:

> The peripheral general lymphatic channels appear to be developed by the confluence of spaces independent of the venous system, although closely associated with the same. * * * They begin as minute extra-venous vacuoles, closely applied to the surface of the veins which they accompany. They enlarge as the lumen of the vein diminishes. They become confluent with each other, but never contain red blood-cells, nor do they communicate with the blood channels.

Huntington believes, however, that the jugular lymph sacs are "direct derivatives of the early, redundant, embryonal, venous pathways of the precardinal and postcardinal regions, adjacent to and involving their point of confluence to form the duct of Cuvier." [1]

(2) *The theory of the continuous centrifugal outgrowth of four or more venous buds.*—By improving the methods of Ranvier, Miss Sabin (1902, 1904, 1908) was able to inject the lymphatics of very young pig embryos. By injecting India ink into the subcutaneous tissue of the neck and inguinal regions of pig embryos of 18 mm. and over, she obtained a beautiful series of pictures showing the peripheral growth of the superficial lymphatics. Her investigations convince her that the lymphatic ducts are budded off from the venous system. She says: "The lymphatic ducts bud off from the veins in four places: two in the neck, at the junction of the jugular and subclavian veins; and two in the posterior part of the body, from the vein which enters the Wolffian body and which is formed by the union of the femoral and sciatic veins." From these four points of origin the lymphatics grow first along the veins toward the skin to form the superficial lymphatic, and secondly along the aorta and its branches to form the thoracic duct and the deeper lymphatic system.[2]

(3) *The theory of the splitting off of the lymphatic from the venous system by a process of fenestration.*—McClure (1908) describes the formation of the lymph sacs and lymph channels in the cat as follows: The anterior lymph sacs are formed "by the separation of parallel venous channels from the embryonic veins by a process of fenestration, and the subsequent conversion of these channels into definite lymph sacs by a process of growth and fusion." The thoracic ducts are formed by "a series of independent outgrowths which first appear along the common jugular and innominate, and then along the azygos veins exactly in the line subsequently followed by these ducts; these outgrowths are subsequently split off from the veins by a process of fenestration, in a series of isolated, more or less spindle-shaped spaces, which later become confluent with each other and with a process of the jugular lymph sac of the corresponding side to form a continuous system disconnected with the veins, except through the mediation of the jugular lymph sac." [3]

The explanation for these divergent results seems to be found partly in the methods of investigation and partly in the material investigated. After examining a few series of cat and pig embryos, it seems to the writer that the earlier, critical stages of lymphatic development are too masked or passed through too rapidly to warrant us in basing our conclusions upon the study of the mammalian type alone. The phylogenetic history of the lymphatic system and its relation to the blood vascular system needs more careful study. Huntington (1910) has well said: "Any theory of lymphatic development must agree in its postulates with the phylogenetic facts, as far as they have been definitely established." Our knowledge, however, of the lymphatic system of the lower vertebrates is very incomplete. Favaro (1906) and Allen (1907, 1908) have done much to clarify our knowledge concerning the relations between the lymphatic and the blood vascular system in fishes. Much more work of this kind is greatly needed to fill up the many gaps still existing in our knowledge of the lymphatics of lower vertebrates. The literature of the ontogeny of the lymphatic system of lower vertebrates is still more scanty. Outside of the mammals, it is limited almost entirely to the paper by Sala (1900) on the lymphatics of the chick, and by Knower (1908) and others on the frog.

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[1] The Anatomical Record, vol. 2, page 25.

[2] American Journal of Anatomy, vol. 3, p. 183.

[3] Anatomischer Anzeiger, Band 32, S. 533 and 542.

The injection of the lymphatics with India ink gives very beautiful demonstrations of the spread of the lymphatic ducts from their point of origin. But this method alone does not prove conclusively that they are the continuous peripheral outgrowths of certain venous buds; since if the ducts are formed by the confluence of independent mesenchymal spaces it is more than likely that this process proceeds peripherally from the several primary foci; hence the injections would merely show the several stages of progress. A few cat embryos were successfully injected by this method, but have not been studied in sections. The writer hopes to prepare a series of turtle embryos by this method during the present summer for comparison with the reconstructions prepared from serial sections.

The choice of a suitable fixing agent is a very important factor to be taken into account. In turtle embryos, where the integument is so thick and the tissue composing it is so very compact, this becomes very apparent. In embryos fixed with corrosive sublimate mixtures, it was impossible to study the intercellular mesenchymal spaces with any degree of satisfaction.

The results of the investigation of the development of the posterior lymph hearts of the loggerhead turtle by the means of serial sections seem to indicate that the mesenchymal spaces play a much greater part in the development of the lymphatics in general than is usually supposed. It appears as though these spaces had captured, as it were, certain capillaries and had converted them into the anlagen of the lymph hearts. This process takes place very rapidly, even in the turtle, so that it might easily be overlooked. As soon as the mesenchyme begins to condense around the veno-lymphatic spaces the process is so masked that, if it still continues, it is no longer recognizable.

SUMMARY.

(1) The development of the posterior lymph hearts of turtles is initiated by the vacuolation of the postiliac mesenchymal tissue during the middle and latter part of the second week of development.

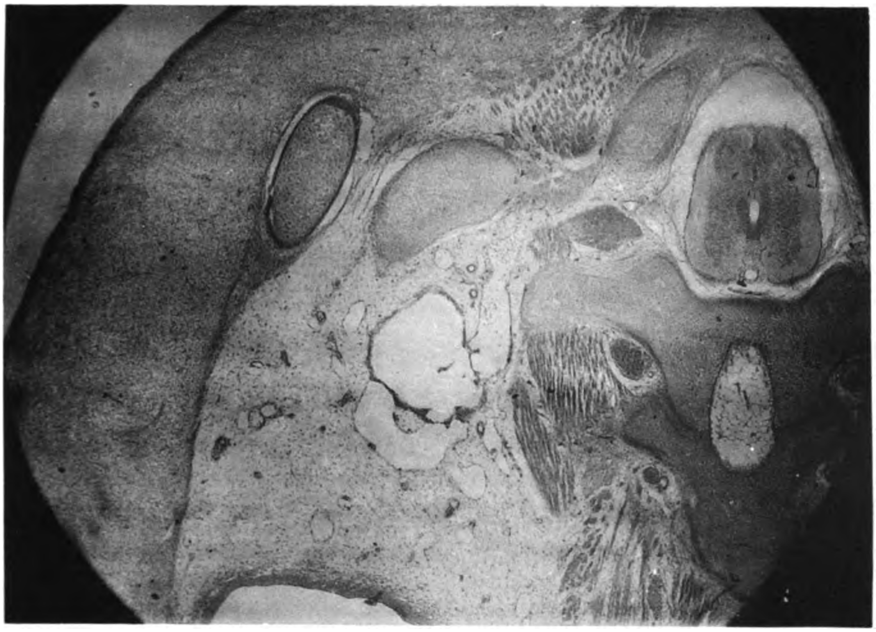
(2) The spongy tissue thus formed is then invaded by capillaries from the first two or three dorsolateral branches of the caudal portion of the postcardinal veins.

(3) Near the close of the third week, parallel veno-lymphatic channels are formed in this spongy area by the confluence of the mesenchymal spaces with each other and with the invading capillaries. These channels

anastomose freely with each other and communicate, by means of two or three openings, with the vein running along their mesial borders.

(4) At the beginning of the fourth week, the mesenchymal tissue condenses about the veno-lymphatic channels to form definite walls. These cardiac walls are then invaded by muscle cells from the adjacent muscle plates.

(5) The final stage in the development of the posterior lymph hearts is reached by the dilation and confluence of these veno-lymphatic sinuses, from before backward, forming a pair of sac-like organs, each with a single central cavity.



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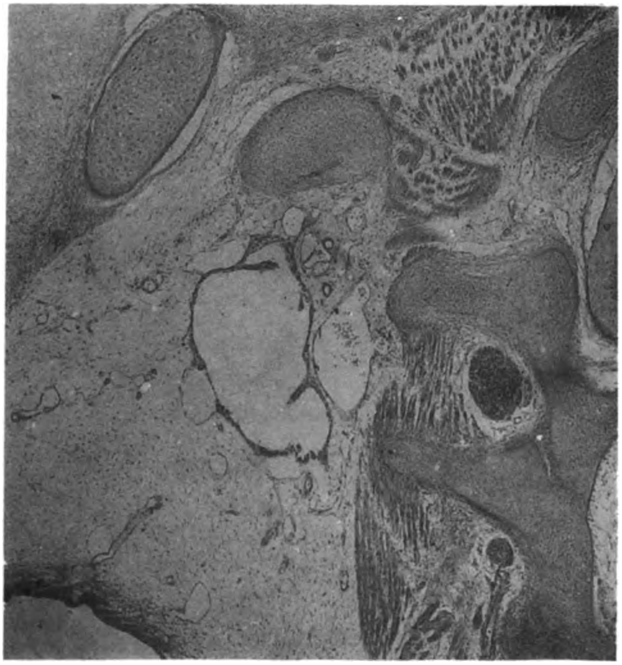
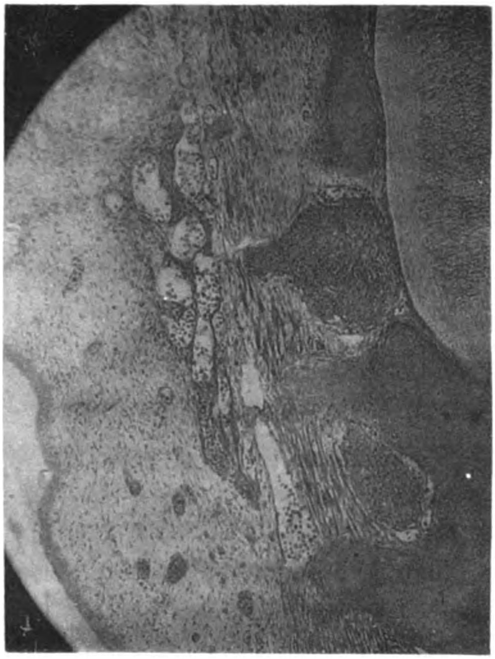


B.

A, Transverse section through Lymph Heart of Loggerhead Turtle Embryo No. 228 (82 days), showing relation of Lymph Heart to Vein and Lymph Channels. (Photo-micrograph.)

B, Photo-micrograph of transverse section taken through Anterior Portion of Posterior Lymph Heart of Loggerhead Turtle Embryo No. 228 (82 days).



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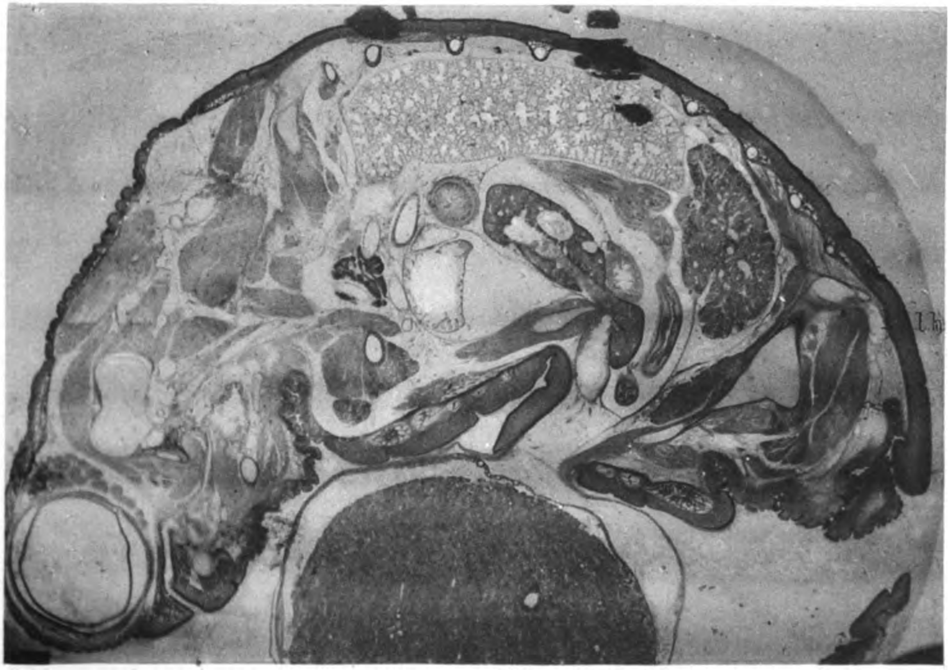

B.

A, Transverse section through Lymph Heart of Loggerhead Turtle Embryo, No. 236 (25 days). (Photo-micrograph.)

B, Photo-micrograph of a Sagittal Section taken through Loggerhead Turtle Embryo, No. 80 (38 days), showing position of Posterior Lymph Hearts in Body of Embryo.

IX.

POLYCITOR (EUDISTOMA) MAYERI NOV. SP., FROM THE TORTUGAS.

By DR. R. HARTMEYER, PH.D.
Of the Berlin Zoological Museum.

I plate.

POLYCITOR (EUDISTOMA) MAYERI NOV. SP., FROM THE TORTUGAS.

By R. Hartmeyer.

Among the ascidians I collected in 1907 at the Tortugas, and concerning which I published a preliminary note in 1908 (Year Book Carnegie Institution of Washington, No. 6, p. 110), there is a new and very interesting species of *Polycitor*, a genus not hitherto known, from the West Indies. I name this new species *Polycitor* (*Eudistoma*) *mayeri*, in honor of Dr. Alfred Goldsborough Mayer, director of the Department of Marine Biology of the Carnegie Institution of Washington.

Polycitor mayeri is the largest and most beautiful ascidian of the Tortugas. It was collected in the deeper water of the Southwest Channel near Loggerhead Key, on sandy or muddy bottoms, where it seems to be fairly abundant and where it lives together with many other species of ascidians, most of which are wanting on the reefs or in the shallow water inside of the reefs.

The colony varies in shape. It usually consists of a more or less club-shaped mass (fig. 1), supported by a short peduncle. There is no distinct constriction at the (upper) distal end of the peduncle. Sometimes the colony forms an irregularly rounded or ellipsoidal mass, laterally little compressed, the area of attachment being broad. In one case, the lower end is prolonged on one side to form a thin expansion by which the colony probably was attached. In some cases two or three masses of different sizes are united and attached by a common base. In its variable shape *Polycitor mayeri* resembles *Macroclinum pomum* (Sars). The length of the largest club-shaped colony is 70 mm., the greatest breadth 35 mm., and the greatest thickness 27 mm. A smaller one is 52 mm. in length, 27 mm. in greatest breadth, and 21 mm. in greatest thickness. On the other hand, one of the rounded, broadly attached colonies measures 30 mm. in length, 44 mm. in greatest breadth, and 23 mm. in greatest thickness. There are some much smaller club-shaped colonies in the collection, not over 20 mm. in length.

The lower part of the colony, especially the peduncle, is incrusted with sand grains, fragments of shells, small stones, serpula-tubes, etc. The upper part of the colony is free from any foreign bodies, the surface being perfectly smooth and glistening.

The color is pale yellowish with a reddish or violet tint. Specimens preserved in formalin have become milky-white; alcoholic specimens are more transparent, so that the ascidiozooids can be more or less distinctly seen as yellow spots.

The test is firm and cartilaginous; small sand grains are included in the interior of the test, but not in great quantity.

Each colony contains several parasitic amphipods.

In some parts of the colony the ascidiozooids are arranged in regular, circular systems of 5 to 6. In other parts no distinct systems are visible. The ascidiozooids are large, reaching 5 to 6 mm. in length. They are rather closely placed and lie at right angles to the surface.

The preserved specimens are of course more or less contracted. In one colony, I found an abdomen apparently very little if at all contracted, measuring 9 mm. (fig. 3). In the living condition ascidiozooids may therefore reach 12 mm. or more in length.

The abdomen is about three or four times as long as the thorax. From the posterior end of the abdomen or from the ventral side near the posterior end one or, more rarely, two ectodermal processes (vascular appendages) are usually given off (fig. 5), which vary in length and sometimes are wholly wanting. The siphons are well developed, provided with strong musculature, and both 6-lobed. They are of equal length or the atrial siphon is a little longer than the branchial siphon. The branchial sac was very much contracted. There are only three rows of long, narrow stigmata.

The alimentary canal forms a very long and narrow loop and is not twisted (fig. 2). The œsophagus and intestine are both very long and straight. The stomach is smooth-walled and situated near the posterior end of the abdomen in the long axis of the body. In somewhat contracted specimens it is heart-shaped or nearly globular in outline (figs. 2, 4); in others which were not contracted it is of ellipsoidal or fusiform shape (fig. 3). Leaving the stomach the intestine bends dorsally for a short length and then extends straight anteriorly. The rectum lies along the œsophagus on the left side, and is partly covered by it (fig. 2). In some ascidiozooids the course of the alimentary canal was somewhat different. The stomach was situated on the dorsal side; the intestine leaving the stomach turned first ventrally and then backward dorsally, passing the stomach on the left side (fig. 4). Intestine and rectum contained several fecal pellets.

The testes were developed in only some of the ascidiozooids. They are pyriform and very numerous, 30 to 40 in number, situated near the posterior part of the stomach (fig. 4) or covering the right side of the stomach (fig. 6). None of the specimens examined contained eggs or embryos.

Polycitor mayeri is one of the largest and most beautiful species of the genus *Polycitor*. On account of the number of the rows of stigmata and the smooth-walled stomach it belongs to the subgenus *Eudistoma* Caull. It seems to come nearer to *Polycitor* (*Eudistoma*) *mucosum* Drasche, from the Mediterranean, than to any other species of the genus, but differs from it in shape and color of the colony as well as in the length and some other anatomical details of the ascidiozooids, so that it is doubtless a distinct and well-marked species. It is not only the first-known *Polycitor* from the West Indies, but from the whole eastern coast of the American continent.

From the western Atlantic only five species of this genus have been described, and all of these are mentioned by Van Name from the Bermudas, but all these species have four rows of stigmata in the branchial sac and are in many other respects quite different from our species.

DESCRIPTION OF PLATE.

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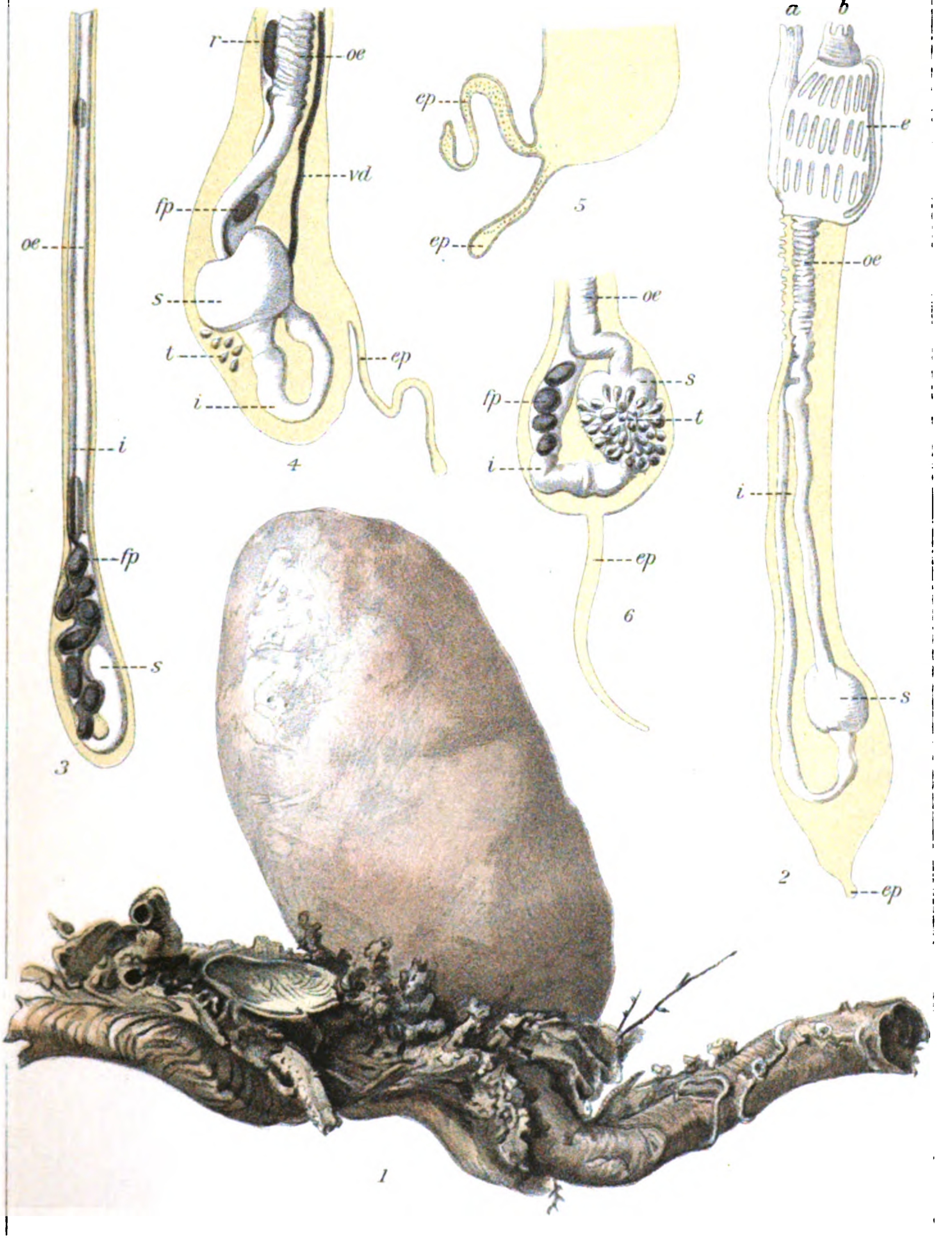
a, atrial aperture;
b, branchial aperture;
e, endostyle;
ep, ectodermal processes;
fp, fecal pellets;
i, intestine;
oe, œsophagus;
r, rectum;
s, stomach;
t, testes;
vd, vas deferens.

1. Largest colony of the collection; natural size.
2. *Ascidiozooid*, from the right side; magnified (ca. 16×).
3. Part of abdomen of another ascidiozooid, very little contracted; magnified (ca. 10×).
4. Part of abdomen of an ascidiozooid, with stomach situated dorsally; magnified.
5. Posterior end of the abdomen of an ascidiozooid with two ectodermal processes; magnified.
6. Posterior end of abdomen of an ascidiozooid with fully developed testes; magnified.



B. Mei[illegible] del.

Polycitor (Eudistoma) mayeri nov. sp.

X.

REACTION TO LIGHT AND OTHER POINTS IN THE BEHAVIOR OF THE STARFISH.

By R. P. COWLES,
Associate in Biology in Johns Hopkins University.

6 text figures.

REACTION TO LIGHT AND OTHER POINTS IN THE BEHAVIOR OF THE STARFISH.

By R. P. Cowles.

The experiments described below deal largely with the reactions of starfishes to light. Two species are used, namely: *Astropecten duplicatus* and *Echinaster crassispina*, both of which occur near the Tortugas group off Key West, Florida.

Echinaster crassispina is rather common in the latter part of June (1900) on the sandy and flat rocky bottom at the south side of Boca Grande, one of the keys lying between Key West and Tortugas. In this region the bottom is fairly level and much of it is of white sand; in some places, however, flat stretches of rock extend horizontally above the level of the sand and these are often covered with algæ, corallines, gorgonia, etc. The echinasters usually live in about 2 feet of water at low tide and they seem to be distributed irrespective of the character of the bottom, about as many being found on the white sand as on the rocky places. They are decidedly migratory and use their tube feet in moving about over the sand in much the same manner as human beings use their legs. This characteristic was observed by Romanes and Ewart (1881) and by Preyer (1886–1887). Recently Jennings (1907), in his usual clear manner, has studied and described the behavior of the tube feet of *Asterias forreri* de Loriol, confirming the observations of the earlier workers. Unlike *A. forreri*, the suckers of *E. crassispina* and *A. duplicatus* do not adhere tightly to the substratum as a rule, nor do these two species usually occur on the under side of rocks.

The rather level character of the bottom on which *Echinaster* lives leads one to believe that the animal is seldom turned over and therefore seldom finds it necessary to right itself. I can hardly believe that this turning over occurs so often that an echinaster would have a chance to form a habit of righting itself on any one pair of rays, but there might be some structural peculiarity which would determine the pair to be used.

Echinaster lives in the open and seems always to be found in regions exposed to the brightest light. In this respect it differs from *A. forreri*. So, as would naturally be expected, we find that in experiments in the laboratory *Echinaster crassispina* reacts positively to bright light and *Asterias forreri* reacts negatively.

Astropecten duplicatus has somewhat similar habits to those of *Echinaster*. It lives usually in deeper water, being found at a depth of 1 or 2 fathoms. It is migratory, but suckers on the tube feet seem to be practically absent. This form also lives on the sandy bottom and reacts positively to bright light.

Note.—I wish to express my thanks to the Carnegie Institution and to Dr. Alfred G. Mayer for the privilege of working in the Tortugas Laboratory.

DOES ONE RAY HAVE GREATER FUNCTIONAL VALUE IN LOCOMOTION THAN ANOTHER?

The experiments of Preyer (1886–1887), in which he tested several species of starfish to see if one ray had greater functional value than another in locomotion, seem to answer the question in the negative except in the case of a specimen of *Astropecten pentacanthus*, which showed a decided tendency to use ray 4 (*d* of Jennings's paper and my own) as director. In general, however, Preyer concluded that one ray has no greater functional value in locomotion than another (fig. 1).

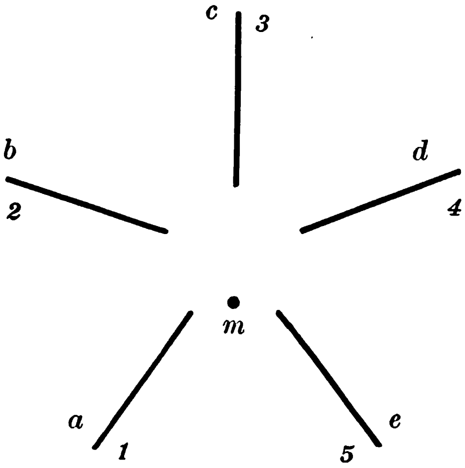


FIG. 1.—Diagram of a starfish in the normal position, i.e., with aboral surface uppermost. The labeling of the rays by numerals is that used by Preyer and Bohn; the labeling of the rays by letters is that used by Jennings, Cole, and the writer. The madreporic plate is indicated by the black spot and is labeled *m*.

While Jennings (1907) in his work on the starfish has not taken up this particular problem, he has made a rather extensive study in order to determine if *Asterias forreri* de Loriol tends to right itself on any special pair of rays and he concludes that the rays lying close to the madreporic plate are more often used than any others.

Bohn (1908) finds that specimens of *Asterias rubens* show "une sorte de préférence pour certains bras," especially when the individuals are of a large size. The rays *3* (*c*) and *5* (*e*) of one individual were used most frequently as directors in locomotion. Bohn, however, does not draw the conclusion that *A. rubens* shows any very definite habit in this respect.

Recently, in a preliminary report (1909), I stated that *Echinaster crassispina* does not show any tendency to use a special ray or pair of rays as a director. This conclusion was based on a considerable number of observations with directive light excluded, but the work was not a careful statistical study such as that undertaken by Cole (1910). The latter finds that *Asterias forbesii*, in the absence of directive stimuli, moves most often with the ray (*e*) in advance and it is possible that if *Echinaster crassispina* is subjected to similar tests a tendency to move with a certain ray in the lead may be shown.

CLIMBING OF VERTICAL WALLS.

Most naturalists who have observed starfishes in their natural habitat have seen them attached to the vertical walls of rocks, masonry, or the piles supporting docks, and those who have studied these interesting animals in the laboratory have been struck by what seems to be their general tendency to climb up on the more or less vertical side of the aquarium, often reaching the surface of the water and apparently attempting even to crawl on this surface with the oral side uppermost. It seems to me the "tendency of these animals to move upward" is more evident in laboratory aquaria than under natural conditions.

Preyer (1886–1887) was one of the first to call our attention to this phenomenon and he saw in the behavior of starfish and brittle-stars a strong tendency to move upward. Strange to say, he ruled out such factors as lack of air, lack of food, changes in temperature or currents of water, and desire for light, suggesting that parasites sometimes found in the ambulacral furrows might be the cause of the upward movement.

Loeb (1900) very justly pointed out the insufficiency of Preyer's suggestion and also objected to the latter's generalization as to the factors that do not influence the behavior. Loeb states that *Asterina tenuispina* is attracted upward by the light; on the other hand, he seems to be inclined to believe, from his study of *Asterina gibbosa*, that certain starfish move vertically upward on account "of the force of gravity"; that they are "driven there by negative geotropism."

Romanes (1885) makes no attempt to discover any factors that might account for the upward movement of certain starfish, but simply describes their behavior in a tank. He finds that they crawl in a determinate direction and that when a starfish happens to touch a solid body it may continue its direction unchanged or may turn toward the body which it has touched. If while crawling along the floor of the tank a ray happens to touch the perpendicular side of the tank, the starfish may continue its direction of advance unchanged on the floor, feeling the perpendicular side with the end of its rays, perhaps the whole way around the tank; yet it may not ascend or it may go directly up the perpendicular wall.[1]

The starfish *Echinaster crassispina*, which I used in experiments, has well-developed suckers on its tube feet and is able to ascend vertical walls without any difficulty. It lives as a rule on rather level bottoms and is migratory in its habits. When several healthy specimens of this species are put in a medium-sized circular glass aquarium filled with sea-water they begin to move after a short time, usually in a determinate direction, and are soon seen climbing up the vertical sides of the aquarium until they reach the surface. If, instead of the small aquarium, a large one holding 200 or 300 gallons is used, some specimens will climb the walls, others will move along the bottom with one or more rays in contact with the walls; while the ascent of some individuals nearly always occurs, the phenomenon is not so striking as when a small aquarium is used.

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[1] Bohn's (1908) experiments show that light has much to do with "geotropic" reactions; that the same lighting is sometimes followed by an ascent and sometimes by a descent of a vertical surface. Assuming that there is a geotropic factor whose action results in the ascent or descent of vertical surface by a starfish, his observations leave the impression that it is a very variable one.

Several series of experiments were undertaken in order to determine the behavior of *Echinaster* on inclined surfaces in the presence or in the absence of light. In these tests a very simple piece of apparatus was used (fig. 2).

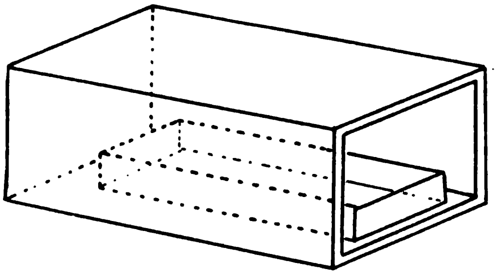

FIG. 2.—Apparatus used to test the effect of great differences of light intensity on starfishes. A glass experimenting dish (36×27×7 cm.) lined with dead-black paper is placed, as shown, in a wooden box (50×32×19 cm.) which is painted dead-black inside and open at one end. The glass dish is filled with sea-water and the whole apparatus is so adjusted that intense sunlight is reflected from a white sand bank into the open end of the box. The top of the box can be removed when starfishes are introduced into the dish.

Before beginning each series the starfish to be used was tested in the apparatus to observe the starfish's reaction to light. The specimen was placed in the dish of sea-water, care being taken to have the bottom of the dish level. The method of handling and the position of the rays with reference to the open end of the box were varied, but almost always the starfish moved toward the light. Rarely the specimen moved to the darker end, but even then it soon returned to the bright end of the apparatus. When the same kind of tests were made, the apparatus being covered with a thick piece of velvet so that no light could enter the open end of the box, the starfish behaved differently, moving more slowly and without reference to any end of the apparatus. Every *Echinaster* and every *Astropecten* experimented with showed a decided tendency to react positively to bright light.

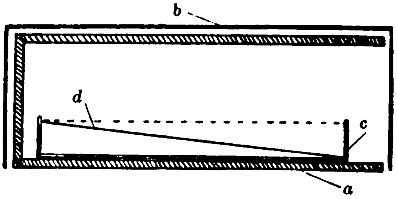

FIG. 3.—Vertical section through apparatus shown in fig. 2, with the addition of the false bottom inclined at 10°, and the light-tight velvet cover. *a*, wooden box; *b*, velvet cover; *c*, glass dish; *d*, inclined false bottom.

After observing the starfish's behavior toward light, as described above, a false bottom inclined at an angle of 10° was placed in the glass dish and so arranged that the base of the incline was at the open end of the apparatus (fig. 3). The results of these tests are as follows:

TABLE 1.

Test.	Orientation.	Direction of locomotion.
1	*a* + *e* toward light........	To base of incline.
2	*c* + *d* " "	" " " "
3	*a* + *b* " "	" " " "
4	*d* + *e* " "	" " " "
5	*b* + *c* " "	" " " "

The starfish, it will be seen, moved to the lightest end of the apparatus and in so doing climbed down the incline. In order to observe the behavior without the light stimulus the apparatus was now covered with a thick piece of velvet, so that it was light-tight. The results were as follows:

TABLE 2.

Test.	Orientation.	Direction of locomotion.	Test.	Orientation.	Direction of locomotion.
1	$a + e$ toward base...	To base.	9	$a + b$ toward base...	To base.
2	$c + d$ " "	To top.	10	$b + c$ " "	To top.
3	$d + e$ " "	To base.	11	$a + e$ " "	To base.
4	$a + b$ " "	To base.	12	$c + d$ " "	To base.
5	$b + c$ " "	To top.	13	$a + b$ " "	To top.
6	$a + e$ " "	To base.	14	$d + e$ " "	To base.
7	$c + d$ " "	To top.	15	$b + c$ " "	To base.
8	$d + e$ " "	To base.			

The results of these 15 tests show that the direction of locomotion is quite variable. There is no strong tendency to ascend or descend the incline, although it is true that the descent was made 10 times out of the 15. Whatever this may mean, there is surely no strong tendency to climb a floor tilted at 10°; there is no indication of "negative geotropism"; they are not "driven there by negative geotropism."

Light is undoubtedly a very strong stimulus in the tests listed in table 1, and one might claim that it resulted in the formation of a habit in which the descent of the incline was associated with strong light entering the open end of the box and that this habit was not overcome by the negative geotropic stimulus. For this reason a series of tests was undertaken like those given in tables 1 and 2 except that the false bottom was so placed that the top of the incline was at the open end of the apparatus and the base at the other. The results of the tests with light as a factor are indicated in the following table:

TABLE 3.

Test.	Orientation.	Direction of locomotion.
1	$a + e$ toward light........	To top of incline.
2	$b + c$ " "	" " " "
3	$d + e$ " "	" " " "
4	$a + b$ " "	" " " "
5	$c + d$ " "	" " " "

It will be seen that the starfish moved to the lighted end of the apparatus in every case, and in so doing mounted the incline.

Light was now excluded by covering the apparatus with velvet. The results of the tests were as follows:

TABLE 4.

Test.	Orientation.	Direction of locomotion.	Test.	Orientation.	Direction of locomotion.
1	$b + c$ toward top....	To base.	9	$c + d$ toward top....	To base.
2	$d + e$ " "	To top.	10	$a + e$ " "	To top.
3	$a + b$ " "	To base.	11	$b + c$ " "	To base.
4	$c + d$ " "	To top.	12	$a + b$ " "	To base.
5	$a + e$ " "	To top.	13	$d + e$ " "	To top.
6	$b + c$ " "	To base.	14	$c + d$ " "	To top.
7	$d + e$ " "	To top.	15	$a + e$ " "	To side.
8	$a + b$ " "	To top.			

In these 15 tests (table 4) it will be seen that the starfish moved to the top of the incline 8 times, to the base 6 times, and to the side once. Although the ratio is slightly in favor of movement up the incline, yet we are not justified in considering that a case of "negative geotropism" is demonstrated. Surely the direction of locomotion is not stereotyped. While it would be desirable to have more data, I think one may draw the conclusion that when *Echinaster crassispina, which usually reacts positively to bright daylight and which usually crawls to the top in a small aquarium exposed to light, is placed on a surface tilted at an angle of 10° (light being excluded), there is no decided tendency for it to move either negatively or positively to the attraction of gravitation.*

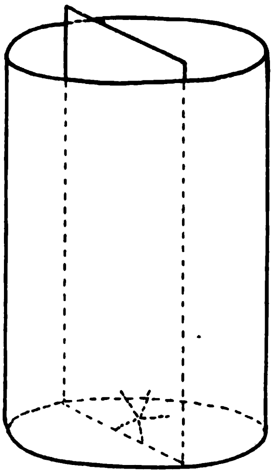

Fig. 4.—Glass cylindrical aquarium with vertical glass plate set inside Used for observing the behavior in climbing tests.

In order to test further the behavior of *Echinaster* on vertical walls, several series of tests were made, using a very large cylindrical glass aquarium filled with sea-water. Inside the aquarium was fixed a flat piece of glass in a vertical position (fig. 4). A specimen which had been tested and found positive in its reaction to light was then allowed to attach itself to the vertical plate, with one or two of its rays resting on the bottom. The apparatus was then covered with a thick velvet cloth, so as to be light-tight. The specimen climbed to the top. 10 tests were made with the following results:

TABLE 5.

Test.	Orientation.	Direction of locomotion.	Test.	Orientation.	Direction of locomotion.
1	*d* + *e* toward top ..	To top.	6	*a* toward top ..	To top.
2	*a* + *b* " "	To top.	7	*b* " "	To bottom.
3	*c* + *d* " "	To top.	8	*c* " "	To top.
4	*a* + *e* " "	To top.	9	*e* " "	To top.
5	*b* + *c* " "	To top.	10	*d* " "	To top.

In 9 tests out of the 10 the starfish ascended the vertical wall and in 1 test descended to the bottom. The results seemed to indicate a strong tendency to ascend, even with light excluded. In these tests, however, the starfish was exposed to light while it was being allowed to attach itself, and it occurred to the writer that during that time the light stimulus might have resulted in the formation of an impulse to move toward the light and that in the attempt to do so it climbed the wall. Accordingly a series of tests was made in a photographic dark room where no light was allowed to reach the starfish except the brief flash from an electric hand-lamp when the creature had completed its test. The results of 20 trials, 8 with the starfish used in table 5 and 12 with another specimen, in which the orientation and handling were varied, show a descent of the vertical wall in 14 tests and an ascent in 6 tests. These trials were made at intervals of 3 minutes. The temperature of the water in the ocean was 29° C. and that in the aquarium 30° C.

It is certain that many starfish show a decided tendency to climb the vertical walls of a small aquarium when exposed to light; it is also true that starfish while climbing a wall are under the influence of the attraction of gravitation; there is no doubt that in going up a wall they move in an opposite direction to that of the attraction of gravitation; but it does not follow that the behavior in question is caused by "negative geotropism," i.e., by the "action of the force of gravity" (Loeb, 1900, p. 71). It does not seem to me that starfish in an aquarium show this decided tendency because of the influence the attraction of gravitation has over them, but that *the climbing is simply incidental, the result of the surroundings.* The explanation of this behavior must be sought in the stimuli received by the starfish before it was placed in the aquarium, in the stimuli received while in the aquarium, and in the physiological state of the animal. These factors together finally result in the "impulse" (Jennings) to move in a determinate direction. *If there is light of much intensity coming from a certain direction the impulse will be such that in the majority of cases the starfish will move toward the source. In so doing if in an aquarium it will soon come to the vertical wall. A characteristic of the starfish is that when once the impulse to move in a certain direction is formed, the starfish is quite persistent in its behavior and continues to move in that direction; so when the creature reaches the wall it ascends owing to the persistence of the impulse strengthened by the continued stimulus produced by the light.*[1]

REACTION TO LIGHT.

Echinaster crassispina is a starfish which lives on a more or less flat sea-bottom and which does not crawl under stones and attach itself as does *Asterias forreri.* It lives in the open and is exposed to the sunlight throughout the day.

We find *Echinaster* reacting positively to bright light while *Asteria* reacts negatively. *Echinaster* is very sensitive to light and, as we shall see, light perception is not confined to the "eye-spots" at the tips of the rays. A large part of the aboral surface at least seems to be sensitive to light stimuli. Not only does *Echinaster,* as a rule, react positively to intense light, but it is also sensitive to a light of 2 to 3 candle-power, or even to a light of somewhat less intensity when placed in a dark room.

Light is undoubtedly a very important factor in determining the movements of *Echinaster.* The dependence of this starfish on light stimuli is shown in its behavior when placed in the dark. The rate of locomotion usually becomes reduced and the tips of the rays turn upward as if in search of the customary light stimulus. Sometimes a specimen is found lying perfectly still on the bottom of an aquarium with all five rays curled upward. *Echinaster* usually assumes an exceptional attitude in the absence of light or in light of very reduced intensity, just as *Asterias forreri* does in the presence of bright light.

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[1] Jennings (1907) has recognized the persistence in behavior after an impulse is formed in the starfish, and Morgulis (1910) has recently drawn attention to a neglected factor in the movement of the earthworm, namely, the tendency to move in a straight line and the obstinate maintenance of a path when once assumed.

While *Echinaster* is very sensitive to light and usually reacts positively to it, such is not always the case. I have described above the reaction of this starfish when placed in a black-lined box with bright light entering one end. Under these conditions the specimen usually moves almost directly toward the lighted end of the apparatus. Making a few tests of this sort, one might draw the conclusion that the starfish's behavior is invariable, that it is stereotyped; but if enough series of tests are made it is found that occasionally the starfish does not react positively to the light. Furthermore, it frequently occurs that when a starfish reaches the lighted end of the dish, instead of staying there it returns again to the dark end, especially when it follows the base of the vertical walls of the dish. Bohn (1908) and, above all, Jennings (1907) lay stress on the importance of not neglecting the internal factors while studying the behavior of the starfish and they recognize the variability of the reactions.

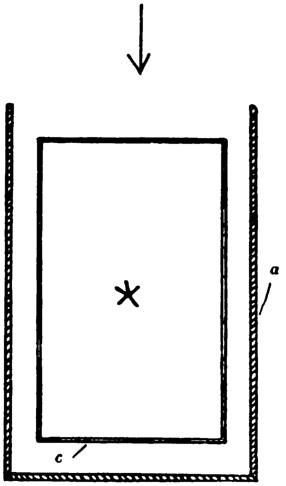

FIG. 5.—Plan of apparatus used in test 1, table 6. The arrow indicates the direction of light. *a*, wooden box; *c*, glass dish.

REACTION TO BRIGHT LIGHT.

Using the apparatus shown in fig. 2, many echinasters were tested to determine their reaction to the intense light reflected from a white sand-bank. The starfish was placed in the experimenting dish, with a single ray or with an interradius directed toward the lighted end. The method of handling was varied. Many series of tests were made and in the large majority of cases the starfish reacted positively and moved to the brightly lighted end of the dish. Under the influence of the intensely lighted region at the open end of the apparatus the specimens seldom failed to react positively, but the reaction was not invariable.

The results of these experiments show that *Echinaster*, as a rule, reacts positively to regions of increased light intensity, that it does this irrespective of the ray or rays directed toward the bright light, and that its locomotion is somewhat more accurate when a ray is pointed toward the light than when an interradius is directed in that direction. Fig. 5 is a plan of the apparatus as used in tables 6 and 7. Table 6 records a series of tests with a single ray directed toward the bright end. Table 7 records tests with an interradius directed toward the bright end.

TABLE 6.

Test.	Orientation.	Direction of locomotion.
1	*c* toward light........	Directly to light end.
2	*e* " "	" " " "
3	*a* " "	" " " "
4	*b* " "	" " " "
5	*d* " "	" " " "

While I suppose it will not be doubted that light has a directive influence on the direction of locomotion of *Echinaster*, yet it may be well to state that series of tests were made in which the entrance of the light into the apparatus was regulated by black screens. Sometimes the light was only allowed to enter by a vertical slit at one corner, sometimes at the other corner, and sometimes in the middle of the open end of the apparatus. As a rule, the starfish moved directly toward the slit irrespective of the latter's position.

TABLE 7.

Test.	Orientation.	Direction of locomotion.
1	*e* + *a* toward light	Directly to lighted end.
2	*a* + *b* " "	" " " "
3	*b* + *c* " "	To lighted end with same rays forward but moved sideways.
4	*c* + *d* " "	To lighted end with same rays forward but moved sideways.
5	*d* + *e* " "	To lighted end with same rays forward but moved sideways.

PARTS SENSITIVE TO LIGHT.

Tiedemann (1815), who was one of the first to study the starfish, came to the conclusion that the whole surface was sensitive to light. This was before the discovery of the eye-spots in the starfish. After these organs had been found, however, they came to be considered as the light-receiving organs. Both Romanes (1885) and Preyer (1886–1887) consider the presence of eye-spots necessary to produce a reaction to light. While Bohn (1908) does not state that the eye-spots are the only organs sensitive to light in the starfish he studied, yet he does not mention any other parts as being sensitive. Uexkull in his numerous papers has not taken up the reaction of starfishes to light, but his experiments with sea-urchins show that these creatures react to differences in intensity of light, even though they have no eye-spots.

In order to determine the effect of the removal of the eye-spots on the reactions of *Echinaster* to light, several individuals were used and each was first tested before the operation in the apparatus shown in figs. 2 and 5. All specimens reacted positively to the light in almost every test and moved to the lighted end of the dish. The tips of the rays of these starfish were then cut off about 1 cm. from the end, so that all the individuals were without eye-spots. The operated starfish were then allowed to recover from the shock under as favorable conditions as possible. Two hours after the amputation the starfish were again tested. The results obtained with one individual are shown below.

TABLE 8.

Test.	Orientation.	Direction of locomotion.	Test.	Orientation.	Direction of locomotion.
1	?	Directly to lighted end.	10	*b* toward light	Directly to lighted end.
2	*c* toward light	Directly to lighted end.	11	*e* " "	Directly to lighted end.
3	*a* " "	Directly to lighted end.	12	*c* " "	Directly to lighted end.
4	*b* " "	To side, then to lighted end.	13	*a* " "	Directly to darkened end.
5	*c* " "	To side, then to lighted end.	14	*b* " "	Directly to lighted end.
6	*c* " "	Directly to lighted end.	15	*d* " "	Directly to lighted end.
7	*d* " "	Directly to lighted end.	16	*c* " "	Directly to lighted end.
8	*e* " "	Directly to lighted end.	17	*e* " "	Directly to lighted end.
9	*a* " "	Directly to darkened end.	18	*a* " "	Directly to lighted end.

The first five of the above tests were made 2 hours after the operation and the balance about 24 hours later. The method of handling and the orientation were varied, but there is every indication that the starfish reacted positively toward the brightly lighted end of the dish. In every test but 2 of the 18, the echinaster moved to the light end. On the second day after the operation the behavior was more direct. There can be no doubt that the eye-spots as well as 1 centimeter of the ray are not necessary in the reaction of *Echinaster crassispina* to the light. The rest of the surface of the starfish must be sensitive to light (Jennings's work indicates this) to such a degree that the direction of movement is influenced by it. In fact, since this work was done I have tested the sensitiveness of the tube feet and the gills of *Pentaceros reticulatus* and have found that they react definitely to changes in intensity of light.

Besides the series of tests recorded in table 8, other series equally convincing were undertaken with different individuals; furthermore, we shall see in some later experiments additional proof that an echinaster without eye-spots is sensitive to light; while there is no doubt that eye-spots are not necessary, yet it is true that echinasters with these organs removed do not react as quickly as normal individuals. Whether this is the result of the injured condition or the lack of the eye-spots I can not say.

DIFFERENCE IN INTENSITY OF ILLUMINATION AND RAY DIRECTION AS FACTORS IN DETERMINING THE DIRECTION OF LOCOMOTION.

So far as I know, Jennings (1907) has been the first to attempt to ascertain whether the direction of the rays of light or the differences in the intensity of illumination on the different parts of the body determine the direction of locomotion of the starfish. By manipulating a screen in various ways, so as to cut out the direct action of the sun's rays on the surface of the starfish, Jennings obtained results which point strongly to the view that the "relative intensity of illumination" is the important factor in the determination of the direction of locomotion.

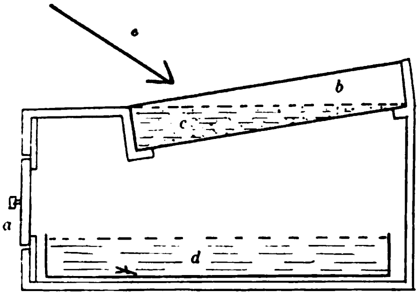

FIG. 6.—Section through the apparatus used to obtain a field of light of graded intensity. *a*, light-tight door; *b*, glass container; *c*, prism of water mixed with a little Higgins waterproof ink; *d*, rectangular glass dish containing sea-water and starfish; *e*, direction of sun's rays.

While many of my experiments led me to believe that the starfish (*Echinaster*) and the brittle-star (*Ophiocoma*) are influenced more by the relative intensity of illumination of the surface of the animal than by the direction of the rays, yet I undertook the following experiments to confirm my belief. A brief preliminary notice of these experiments has been published by the writer (1909). The apparatus (fig. 6) described in that paper consisted essentially of a tight wooden box open above and painted dead black inside. Into this opening was fitted a glass container partly filled with water mixed with a little Higgins waterproof ink, so that when the container was in position there was formed a prism of the solution, thick at one end and thin at the other. A rectangular glass dish lined with dead-black paper and almost filled with sea-water was used for testing the echinasters. This was put within the black-lined box and the whole apparatus was then placed so that the direct rays of the sun entered the prism, thus producing a lighted area in the dish which was of graded intensity.

Four series of tests were made with the sun's rays entering the apparatus in the general direction shown in fig. 6. In each series a different starfish was used; two of the specimens were large and two were small; one of the larger ones had all of its eye-spots removed. Without a heliostat it was impossible to have the light rays enter the apparatus at the same angle in each experiment, but this should make no difference in the results. In one of the four series there were ten tests made; the angle the sun's rays made with the floor of the apparatus varied in each case as follows: 22°, 24°, 25°, 33°, 44°, 45°, 46°, 47°, 50°, 57°. A test consisted of placing an echinaster in about the middle of the dish of sea-water and of observing its direction of locomotion. In every case the starfish moved apparently without hesitation to the bright end of the graded field and remained there for some time. A series of ten tests with the specimen whose eye-spots had been removed gave similar results, except that the reaction was slower.

After testing echinaster with the sun's rays entering as shown in fig. 6, the apparatus was turned around so that they entered from the opposite direction. The results were the same as in the test made above; the starfish moved to the light end of the dish.

A few tests were made with the sun directly overhead and again in every case the starfish moved to the end most intensely lighted.

Finally the apparatus was altered so that the layer of ink and water no longer made a prism. The container was set level, so that the layer of water and ink was of uniform thickness throughout. The result was that the sun's rays produced an area of light of equal intensity in the experimenting dish. Echinasters tested under these conditions moved about "aimlessly," sometimes in the direction of the rays, sometimes opposite to the direction of the rays, and often from side to side.

These experiments, it seems to me, make it evident that *Echinaster crassispina* tends to move from the region of least intensity to that of greater intensity without reference to the direction of the sun's rays.

There has been an objection raised to the use of a prism containing india-ink particles in suspension. It is claimed that the particles of ink disperse the light before it reaches the starfish, so that parallel rays do not strike the starfish. Such is undoubtedly the case, for, as Mast (1907) states: "reflection and refraction can not be entirely eliminated, even with the utmost precaution." The writer does not hold that the rays impinging on the surface of the starfish are parallel. Since the rays are not parallel it may be claimed that the particles at the thin end of the prism reflect the rays and that these rays act as a directive influence resulting in movement toward the bright end of the field; but it is also true that the particles at the thick end of the prism disperse the sun's rays and that many of these reflected rays impinging on the surface of the starfish come from a direction opposite to which the creature is moving. To the writer, it seems impossible that the rays reflected from the extremely minute particles of india ink in the mixture have any directive effect, since it has been found that the behavior is the same, i.e., the starfish moves to the bright end of the field, whether the sun's rays enter the prism as shown in the figure, whether they enter in the opposite direction, or whether they enter vertically.

EFFECT OF TEMPERATURE ON REACTION TO LIGHT.

It has been shown above that *Echinaster crassispina* usually reacts positively to brightly lighted regions, although occasionally the opposite is found to be the case. Several investigators, including Loeb (1893), Massart (1891), and Strasburger (1878), have stated that the sign of reaction of some lower organisms is reversed when the temperature changes from a certain degree to another. On the other hand, Parker (1901), Yerkes (1903), and Mast (1907) find no change in the sign of the reaction in the case of copepods, *Daphnia pulex* and *Volvox globator*.

The writer tested the reaction to light of the starfish *Echinaster crassispina* at different degrees of temperature. The apparatus used is shown in figure 2. It was found that when the temperature of the water was from 29° to 30° C. the reaction to light was at its optimum and that the movement toward the most intensely lighted end of the dish was very definite. A series of tests was made in which the temperature of the water was gradually decreased and also one in which it was gradually increased. The range of temperatures was as follows: 17.8°, 18.4°, 20°, 21.1°, 21.7°, 22.2°, 24.4°, 25.6°, 26.7°, 28.9°, 29.5°, 32.7°, 33.3°, 34.4° C. As the temperature was reduced from 28.9° C. to 17.8° C. the rate of movement toward the brighter end of the dish decreased until locomotion was entirely inhibited at the latter degree. The starfish settled down closely on the bottom of the dish and the tube feet stuck so tightly to the glass that it was impossible to remove them without tearing. This condition is exceptional for *Echinaster crassispina* at ordinary temperatures. On the other hand, when the temperature was increased from 28.9° C. to 34.4° C. the starfish did not adhere to the dish, but its activity was very much reduced and although it continued to react positively the movement was very slow. Above 34.4° C. the starfish became almost lifeless. In no case was there any indication of a reversal of the sign of reaction. The starfish continued to move from the region of least intensity to that of greater intensity.

Bohn (1908) describes an experiment which he considers as an example of change in sign of "phototropisme." He placed an *Asterina gibbosa*, which usually reacts negatively to bright light, in a lighted field. The starfish began to move in a certain direction and was then turned around through 180°; the result was that the specimen then moved in the opposite direction. In other words, a starfish which reacted negatively to bright light by moving away from it, reacted positively to bright light by moving toward it when rotated through 180°. This behavior Bohn interprets as a change in sign of "phototropisme." It is true that *Asterina* changed its direction of movement with reference to the more intensely lighted region, but this was undoubtedly not due to any change in the stimulus produced by light. Such behavior, it seems to me, should be explained by the persistence of the "coördinated impulse" (Jennings, 1907). The starfish had been placed in the lighted field; some stimulus (either the light or other external or internal stimuli) so affected the creature that the tube feet began to move coördinately, resulting in locomotion with a certain ray of interradius directed forward; the asterina moved in a definite direction, namely, *away* from the light; when this impulse was firmly established and the starfish was moving away from the brightly lighted region it was turned through 180°; the established impulse to move with a certain ray or interradius forward persisted and the starfish then moved *toward* the light.

Although I have offered this interpretation of Bohn's experiment, I do not wish to leave the impression that a starfish may not change its sign of reaction to light, as a result, for example, of being subjected to intense light or to darkness for a considerable time. While I believe that the behavior of the starfish with reference to light is largely a matter of the intensity to which it has been accustomed, I have not tried any experiments along this line.

EFFECT OF LIGHT RAYS OF DIFFERENT QUALITIES ON THE REACTION TO LIGHT.

Several investigators have attempted to show that some of the lower organisms exhibit a "preference" or "aversion" for light rays of different qualities. It has been held that animals which react positively to light show an "aversion" to the red and a "preference" for the ultra-violet; and that animals which react negatively to light show a "preference" for the red and an "aversion" for the ultra-violet. It has also been shown that *Daphnia*, which is decidedly positive in its reaction to light, repeatedly collected in the yellow-green region of the spectrum. On the other hand, Bert (1869), Merejkowsky (1881), and Yerkes (1900) have offered evidence to show that what often appears to be "preference" or "aversion" for rays of different qualities is probably nothing more than a difference in reaction to lights of different intensities.

Later I hope to take up the quality-intensity problem, but have here simply recorded the sign of reaction to light of different qualities without reference to the intensity.

Color screens were used, and although these were not monochromatic the transmission was tested by photographic methods so that the quality of the light used was known exactly. The tests were made in an apparatus like that shown in fig. 2, except that the open end of the box was closed. In the closed end was cut an opening into which were fitted the various color-screens. Sunlight was used as a source of light. The results obtained were rather meager, showing only that no one kind of ray is necessary to stimulate *Echinaster*. The following 4 screens cut out: (*a*) ultra-violet; (*b*) ultra-violet and violet; (*c*) violet and blue; (*d*) green, yellow, orange, and red. A series of 10 tests was made with each screen, 17 in all; the orientation and handling were varied. In every series the reaction was decidedly positive, i.e., in nearly every test the starfish moved toward the light without hesitation.

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XI.

THE ANATOMY OF PENTACEROS RETICULATUS.

By DAVID HILT TENNENT and V. H. KEILLER,
Bryn Mawr College.

3 plates, 2 text cuts.

THE ANATOMY OF PENTACEROS RETICULATUS.

By D. H. Tennent and V. H. Keiller.

The following account does not presume to be a complete description of the anatomy of *Pentaceros reticulatus*. Its chief value lies in the figures which are used in its illustration.

During my stay at Tortugas in 1909 I made some use of *Pentaceros* eggs and sperm in experimental work and noted, in making the dissections necessary for obtaining these products, some points in the anatomy which were of unusual interest. These were concerned with the organs of reproduction and with the intestinal cæca.

I preserved a number of these starfish and sent them to Bryn Mawr, where I suggested to one of my students, Miss V. H. Keiller, that she make a study and careful drawings of their structure. Although done under my supervision, full credit for the work must be given Miss Keiller. During the summer of 1910 I again examined fresh material as the basis for this account and in order to make sure that none of the structures shown in the drawings were due to the effect of preservation.

Pentaceros reticulatus (Linck, Linnæus) is the common West Indian starfish which is so familiar in the dried form in which it is exhibited as a curio in the sea-shore shops. Linck (1733) in his "De stellis marinis" gives two figures of *Pentaceros reticulatus*, an aboral view on his plate 41 and an oral view on plate 42.

Müller and Troschel (1842) use the generic name *Oreaster* instead of *Pentaceros*. Perrier (1875) and later systematists have accepted the Linnæan and pre-Linnæan name. Agassiz (1877) and Viguier (1878) have contributed to our knowledge of the skeleton of this form, Agassiz's plate XVI, figs. 1, 2, 4, and 5, and Viguier's plate X, figs. 4 and 5, giving excellent representations of the hard parts of the body.

Clark (1901, p. 237) notes for this species an observation by Mr. George Gray, of the Marine Biological Laboratory at Woods Hole, "that there are two well-marked varieties of this starfish, so different from each other that, were connecting links wanting, they would easily pass for distinct species. One has the rays acuminate, the disk very high, the skeleton comparatively light, and the oral surface quite spiny, while the other has the rays shorter and more rounded, the disk lower, the skeleton very solid and covered with large tubercles; oral surface more granular and less spiny."

Studer (1880, p. 545) mentions differences in the color and form of *Pentaceros turritus* Linck and correlates these with sex. With *Pentaceros reticulatus*, although I was able to verify the observation made by Clark, I could not convince myself that these were sexual differences.

The ground color of the aboral surface of *Pentaceros reticulatus* varies from light yellow to a very deep reddish-brown. The reticulation, on the nodes of which the spines are situated, is brought into sharp contrast with this ground by its usually lighter color. In all of the specimens examined the aboral surface (fig. 6) was light in color with strong, glistening spines bordering the ambulacral grooves.

The body integument is extremely hard and tough. Removal of any part of the wall is best accomplished by the use of a heavy, sharp scalpel.

THE DIGESTIVE SYSTEM.

The anus is large and distinct and may be seen without difficulty, slightly to the left of a line which might be drawn through the madreporic plate to the tip of the opposite arm.

Upon removing the aboral wall one sees the short, cone-like rectum (fig. 2, an.) which arises from the center of the broad, five-sided, pyramidal intestine. Into this large intestine open interradially the ducts of the intestinal cæca (resp.), each of these ducts arising by the union of the single ducts of the cæca of adjacent arms at the inner termination of the interradial septa (i.p.).

The intestinal cæca, two of which lie in each arm and whose ducts reach the intestine as above described, are attached to the aboral body-wall by strong muscular connections. The cæca consist of a single main duct from which arise numerous bladder-like diverticula which are capable of great distention. Upon opening some specimens the cæca were found to be greatly distended. Upon stimulation they slowly contracted, the entire organ shrinking to about one-third of its former size. The contents were watery, although the inner wall of the cæca was found to be slimy.

Beneath the intestine, upon the surface of the stomach in each radius, is what appears at first sight to be a second set of five cæca, each made up of two parts. Further examination shows that these are merely pouches formed by the folding of the upper wall of the pyloric portion of the stomach. They involve the regions into which the ducts of the pyloric cæca open and have a narrow slit-like connection with the stomach. This connection may be greatly widened by straightening out the folds. The pyloric cæca (pyl. cæc.) are large and greatly branched. In color they are brownish-green.

The cardiac portion of the stomach (fig. 5, card. st.) is large and its muscles, both those which are attached along the sides of the ambulacral ridge (retr.) and those attached at the oral ends of the ridges, are powerful.

THE WATER VASCULAR SYSTEM.

The madreporic plate (figs. 1 and 2, madr.) is inconspicuous but may be recognized readily by its color which is lighter than the surrounding ground color, From the plate the stone canal (mad. can.) leads downward to the ring canal (r. c.). From the ring canal are given off the Polian vesicles, the Tiedemann bodies, the ampullæ of the first tube feet, and the radial canals. A large-stalked Polian vesicle (pol. ves.) is present in each interradius except the madreporic. Two Tiedemann bodies are present in each interradius, including that in which the stone canal is situated. The ampullæ (amp.) of the first tube feet arise directly from the ring canal. The radial canal (rad.) runs directly to the tip of the arm. The tube feet lie in a single row on each side of the ambulacral groove, but the ampullæ lie in a double row, an upper and a lower, each tube foot being connected with two ampullæ (fig. 7).

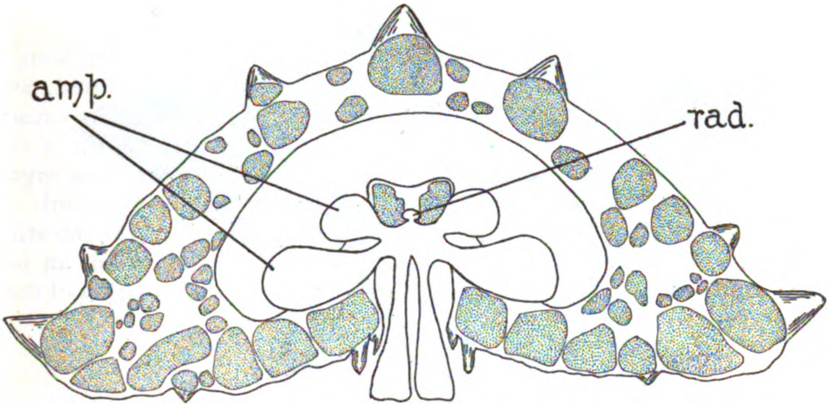

FIG. 7.—Diagram transverse section of arm through ampullæ and tube feet.

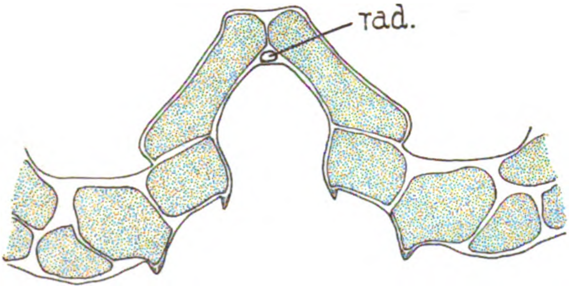

FIG. 8.—Diagram ambulacral groove between ampullæ and tube feet.

THE ORGANS OF REPRODUCTION.

The ovaries (fig. 3, ov.) or the testes (fig. 5, ts.) are in the form of bunches or clusters of short, tubular bodies, each cluster having a separate duct to the aboral surface (fig. 5), upon which it opens by a fine pore. In specimens that I have examined I have found from nine to fifteen clusters down the side of each arm. Each cluster having a separate opening, the genital pores form a row along the side of each arm, in position these rows lying one on each side of the interradial septa. The pores may not be made out directly in either the living or the preserved individuals, but their positions may be seen easily during the discharge of the reproductive elements. The ovaries in the fresh material are orange in color, the testes light yellow or almost white.

THE MUSCULAR SYSTEM.

Although the body-wall is thick and exceedingly stiff the starfish is very mobile. The aboral musculature is shown in fig. 4, where it will be seen that in each arm there are three principal muscle bands, each with numerous branches.

GENERAL.

Of the organs which are described and figured those which seem of greatest interest are the intestinal cæca. These, as above stated, were found in some instances to be greatly distended, stimulation causing their contraction. Upon allowing individuals, from which the aboral wall had been removed, to remain undisturbed in sea-water, the organs again became distended and later contracted of their own accord. In this behavior we have support to the idea of the analogy of the intestinal cæca of the starfish to the respiratory trees of the holothurian, an idea which has been based in the main upon the similarity of position of these organs.

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FIGURES.

Figures 1 to 6 were drawn with crayon on Ross's stipple paper to the full size of the object and have been reduced two-thirds in reproduction.

Abbreviations.

an., anus.
amp., ampulla.
card. st., cardiac portion of stomach.
i. p., interradial septum.
madr., madreporite.
mad. can., stone canal.
op. resp., opening of intestinal cæcum.
ov., ovary.
mes., mesentery.
pol. ves., Polian vesicle.
pyl. coec., pyloric cæcum.
rad., radial canal.
r. c., ring canal.
resp., intestinal cæcum.
retr., retractor muscle of stomach.
Tiedm., Tiedemann body.
ts., testis.

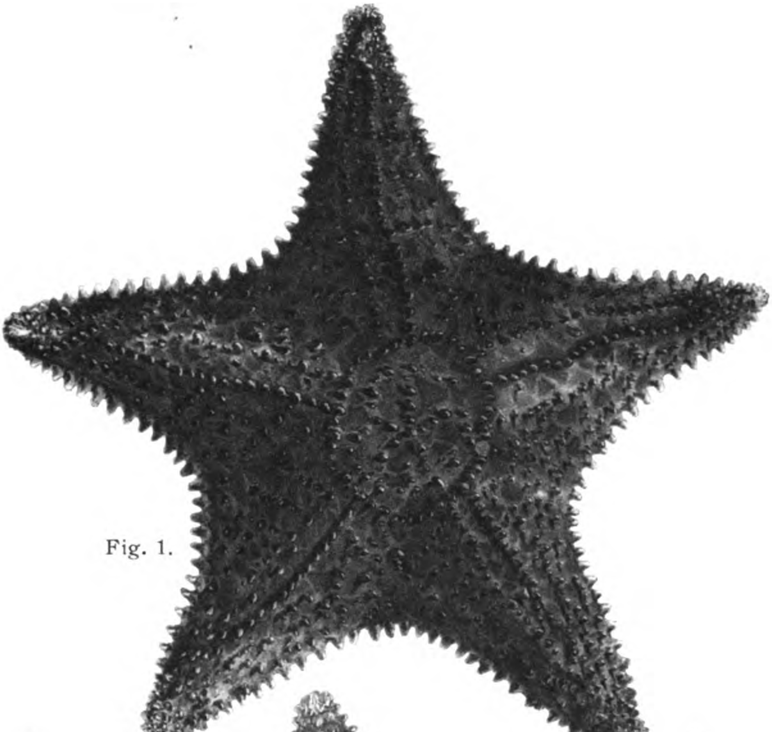

Fig. 1.

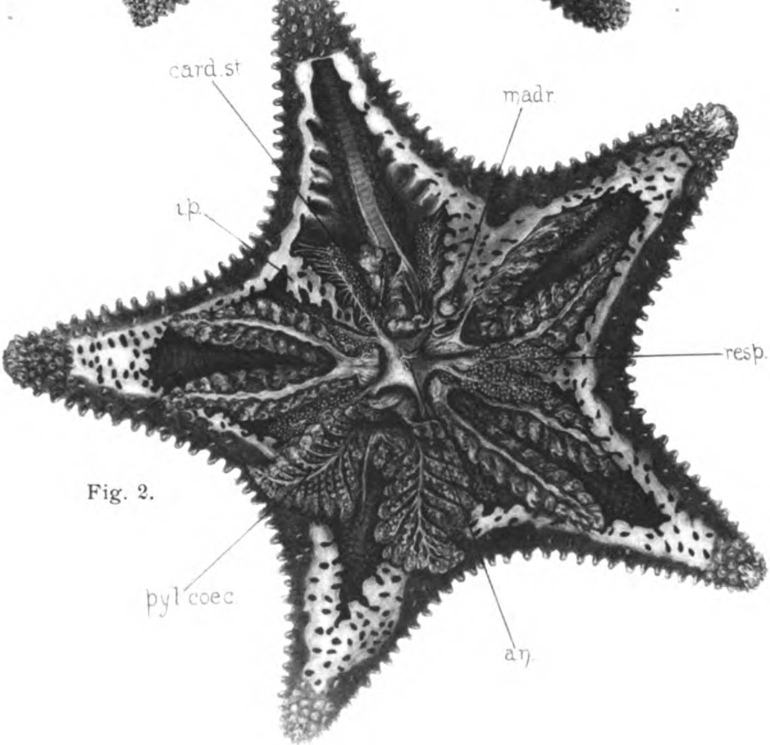

Fig. 2.

V. H. KEILLER DEL.

Pentaceros reticulatus.

1. Aboral surface.
2. Dissection to show digestive system.

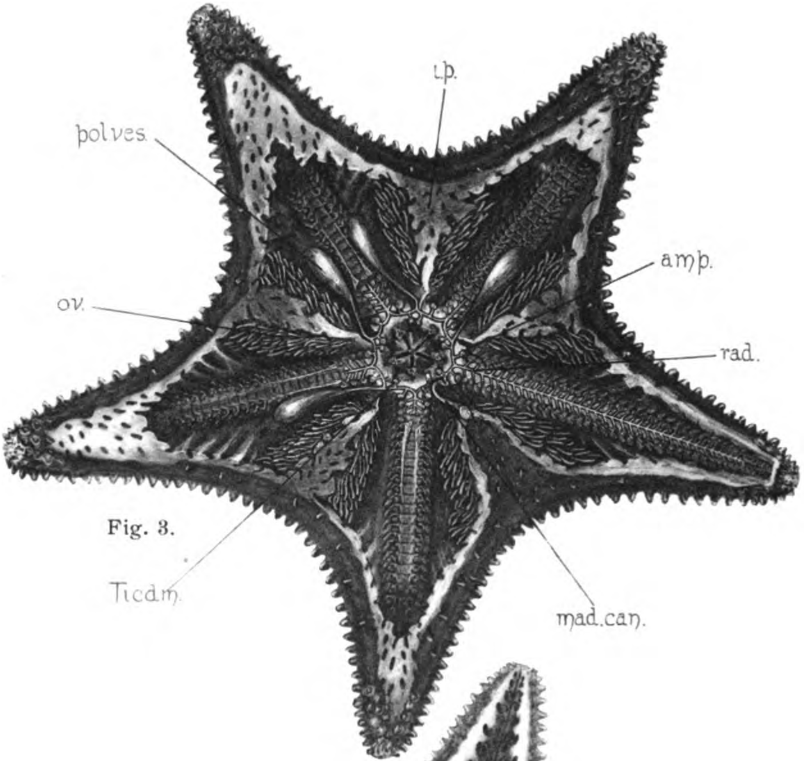

Fig. 3.

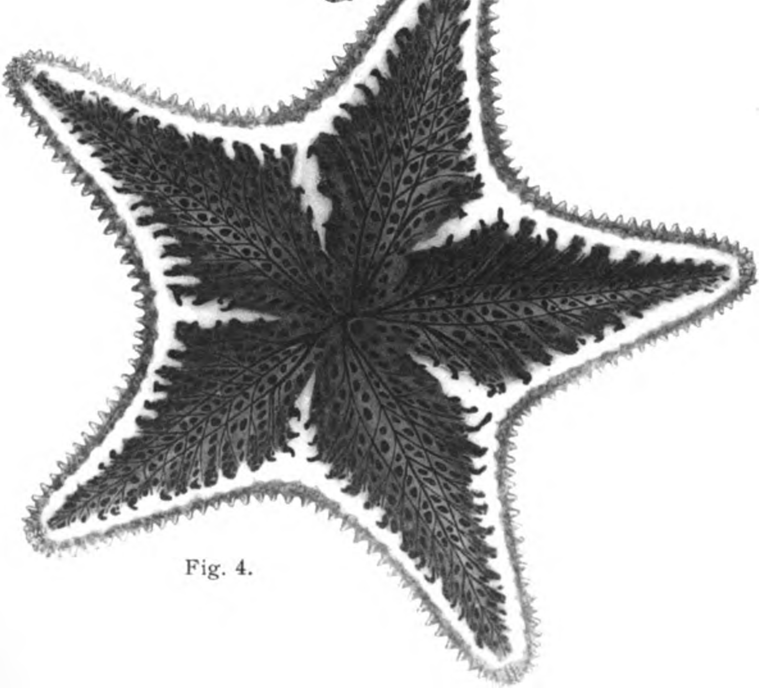

Fig. 4.

V. H. KEILLER DEL.

Pentaceros reticulatus.

3. Dissection to show water-vascular and reproductive systems.
4. Inner surface of aboral body wall, showing aboral musculature.

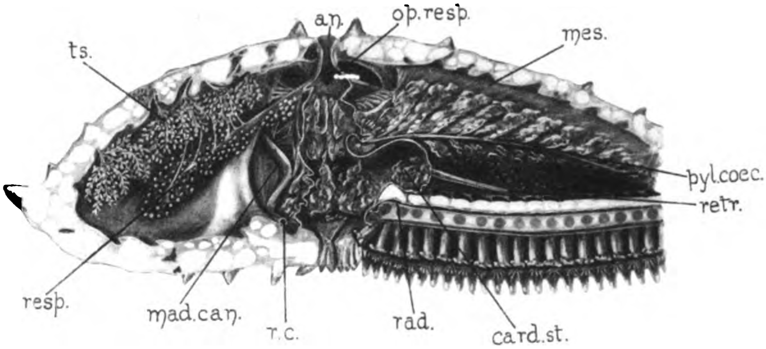

Fig. 5.

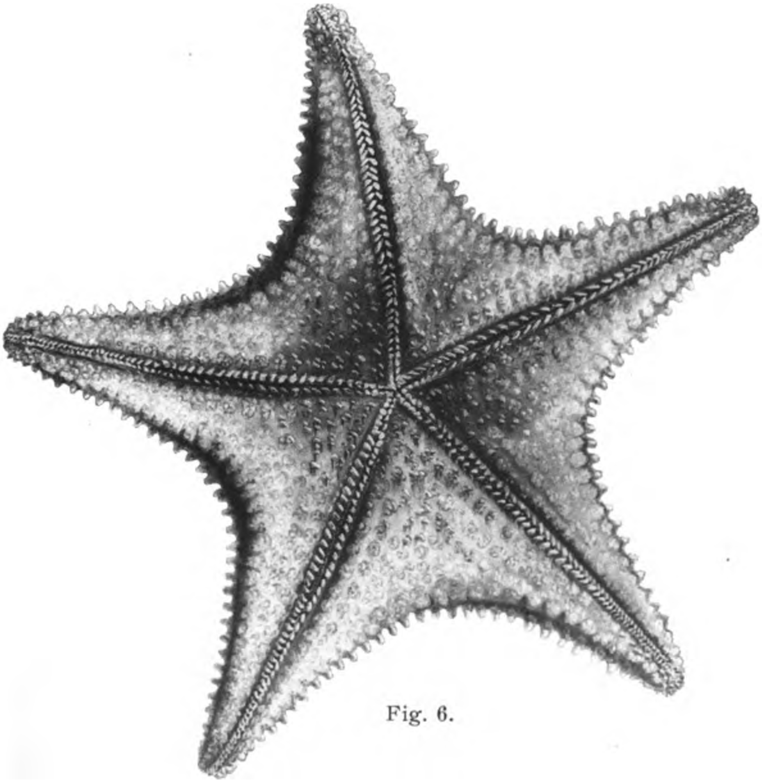

Fig. 6.

V. H. KEILLER DEL.

Pentaceros reticulatus.

5. Section of plane of madreporic interradius.

6. Oral surface.

XII.

ECHINODERM HYBRIDIZATION.

By DAVID HILT TENNENT,
Bryn Mawr College.

6 plates, 7 text cuts.

ECHINODERM HYBRIDIZATION.

By David Hilt Tennent.

In 1907 I began work in the field of Echinoderm hybridization, primarily with the object of obtaining material for a study of the behavior of the nuclear material in cross-fertilized eggs. Some phases of the subject, which in the beginning occupied a secondary place in my mind, have compelled my attention up to this time. The results of these investigations, although incomplete in many ways, are here presented. The study of the nuclear activities will be completed as rapidly as circumstances permit, the mass of my material for this study now being relatively large.

Those who are at all familiar with this subject realize that a knowledge of facts which can be determined only by cytological studies is absolutely necessary before we can reach a definite conclusion regarding the phenomena which are described and discussed in this paper. My own results (Tennent 1908) and the later and more complete observations of Baltzer (1909 *a* and *b*) and of Herbst (1909) have shown that we may expect much from further investigations.

In 1907 at Beaufort I succeeded in making eight crosses,

1. *Arbacia punctulata* ♀ × *Mellita pentapora* ♂.
2. *Arbacia punctulata* ♀ × *Moira atropos* ♂.
3. *Mellita pentapora* ♀ × *Moira atropos* ♂.
4. *Moira atropos* ♀ × *Arbacia punctulata* ♂.
5. *Moira atropos* ♀ × *Mellita pentapora* ♂.
6. *Moira atropos* ♀ × *Toxopneustes* ♂.
7. *Toxopneustes* ♀ × *Mellita* ♂.
8. *Toxopneustes* ♀ × *Moira* ♂.

In 1908, having realized since the work of the previous summer the absolute necessity of a more complete knowledge of variation occurring in plutei raised under laboratory conditions, I made a study of the development of *Toxopneustes variegatus* from the fertilized egg through the metamorphosis of the pluteus into the adult. The account of that study of variation is now in press and will appear in the Journal of Experimental Zoölogy. During the same summer the study of the *Toxopneustes-Moira* cross was continued and some of the plutei derived from this cross were kept alive and in good condition for 45 days.

I wish to express my thanks to the Hon. George M. Bowers, U. S. Commissioner of Fisheries, for the privilege of working in the Beaufort Laboratory, at which this work was begun, and to Mr. Henry D. Aller, Director of the Laboratory, for many courtesies extended to me. I wish also to express my thanks to the Carnegie Institution of Washington and to Dr. A. G. Mayer, Director of the Marine Laboratory at Tortugas, for the splendid opportunity for continuing my investigations and for assistance in completing the plates which are used in illustrating this article. Most of the figures were drawn from the author's sketches by Mrs. Mary T. Walter or by Mr. K. Morita.

In 1909, at The Marine Laboratory of the Carnegie Institution at Tortugas, the scope of the investigation was widened greatly by the acquisition of new forms and the discovery that two of these forms crossed reciprocally with equal facility. This, I believe, has given me more favorable material than has been obtained by any other investigator. The crosses made during this summer are shown in the following list. The *Hipponoē-Toxopneustes* crosses are of especial interest.

1. *Hipponoë esculenta* ♀ (= *Tripneustes esculentus*) × *Cidaris sp.* ♂.
2. *Hipponoë esculenta* ♀ × *Ophiocoma riisei* ♂.
3. *Hipponoë esculenta* ♀ × *Pentaceros reticulatus* ♂.
4. *Hipponoë esculenta* ♀ × *Toxopneustes* ♂.
5. *Toxopneustes* ♀ × *Echinaster sp.* ♂.
6. *Toxopneustes* ♀ × *Hipponoë* ♂.
7. *Toxopneustes* ♀ × *Holothuria floridana* ♂.

In 1910, at Tortugas, experiments with *Hipponoë* and *Toxopneustes* were repeated and the observations of the previous summer were verified.

This paper embodies that part of my work on cross-fertilization in Echinoderms which pertains to the morphology of the embryos obtained, and to methods of controlling the dominance of maternal and paternal characters.

Work on Echinoderm hybridization has been in the main of four types:

(1) Morphological studies, usually simple descriptions of larvæ obtained from various crosses.

(2) Physiological studies, usually investigations of an analytical nature based on observations of the effect of changes in environment and made in the attempt to account for the resemblance of the offspring to one or the other of the parents.

(3) Cytological studies, researches carried on with the aim of correlating microscopic characters of the hybrid material with those of either or both of the parents.

(4) Chemical studies, which have for their aim the solution of the problem of fertilization in particular and in which the Echinoderm egg is used incidentally because of its favorable nature.

It will be a matter of some surprise, even to those familiar with this work, to note the number and variety of the crosses which have been made. In the list on the following page I have included all that have come to my attention.

It is an interesting fact that in most of these cross-fertilizations it is the echinoid egg that has been fertilized by the sperm of other echinoids and of asteroids, ophiuroids, crinoids, holothuroids and mollusks, while reciprocal inter-class crosses have not been reported. This may or may not be a matter of significance. In my own experience I have found that the eggs of *Pentaceros reticulatus* are not readily fertilizable by the sperm of *Hipponoë*, either after being allowed to stand or after treatment with NaOH. In other experiments, in which I subjected the *Pentaceros* eggs to treatment with CO_2 for from 4 to 10 minutes before fertilization, I obtained segmentation, but I am not prepared to say whether the segmentation was parthenogenetically produced or was the result of fertilization.

We have sufficient evidence, I believe, to warrant the belief that each egg requires a certain definite environment for fertilization by foreign sperm. That necessary environment has been determined only for the sea-urchin egg.

TABLE OF SUCCESSFUL ECHINODERM CROSS-FERTILIZATIONS.

- *Arbacia punctulata* ♀
  - × *Mellita pentapora* ♂ (Tennent).
  - × *Moira atropos* ♂ (Tennent).
- *Arbacia pustulosa* ♀
  - × *Dorocidaris* ♂ (Vernon).
  - × *Echinocardium* ♂ (Stassano).
  - × *Echinus* ♂ (Driesch, Stassano, Vernon).
  - × *Sphærechinus* ♂ (Driesch, Hertwig, Stassano).
  - × *Strongylocentrotus* ♂ (Driesch, Hertwig, Vernon).
- *Asteracanthion berylinus* ♀
  - × *Asteracanthion pallidus* ♂ (Agassiz).
- *Asterias forbesii* ♀
  - × *Arbacia pustulata* ♂ (Morgan).
- *Dorocidaris* ♀
  - × *Strongylocentrotus* ♂ (Vernon).
- *Echinocardium cordatum* ♀
  - × *Arbacia pustulosa* ♂ (Stassano, Vernon).
  - × *Echinus* ♂ (Vernon).
  - × *Sphærechinus* ♂ (Stassano, Vernon).
  - × *Strongylocentrotus* ♂ (Vernon).
- *Echinocardium mediterraneum* ♀
  - × *Echinus* ♂ (Vernon).
  - × *Sphærechinus* ♂ (Vernon).
  - × *Strongylocentrotus* ♂ (Vernon).
- *Echinus acutus* ♀
  - × *Arbacia* ♂ (Vernon).
  - × *Sphærechinus* ♂ (Vernon).
- *Echinus microtuberculatus* ♀
  - × *Arbacia* ♂ (Driesch, Vernon).
  - × *Echinocardium* ♂ (Stassano, Vernon).
  - × *Echinus acutus* ♂ (Vernon).
  - × *Strongylocentrotus* ♂ (Driesch, Hertwig, Vernon).
  - × *Sphærechinus* ♂ (Driesch, Morgan, Vernon).
- *Hipponoë* ♀ (= *Tripneustes*).
  - × *Cidaris* ♂ (Tennent).
  - × *Ophiocoma* ♂ (Tennent).
  - × *Pentaceros* ♂ (Tennent).
  - × *Toxopneustes* ♂ (Tennent).
- *Mellita* ♀
  - × *Moira* ♂ (Tennent).
- *Moira* ♀
  - × *Arbacia* ♂ (Tennent).
  - × *Mellita* ♂ (Tennent).
  - × *Toxopneustes* ♂ (Tennent).
- *Psammechinus miliaris* ♀
  - × *Asterias rubens* ♂ (Giard).
- *Psammechinus* (*pulchellus*) ♀
  - × *Spatangus* ♂ (Köhler).
  - × *Sphærechinus* ♂ (Köhler).
  - × *Strongylocentrotus* ♂ (Köhler).
- *Spatangus* ♀
  - × *Strongylocentrotus* ♂ (Köhler).
  - × *Psammechinus* ♂ (Köhler).
- *Sphærechinus* ♀
  - × *Echinus* ♂ (Driesch, Hertwig, Morgan, Vernon).
  - × *Psammechinus* ♂ (Stassano).
  - × *Strongylocentrotus* ♂ (Driesch, Hertwig, Marion, Morgan, Steinbrück, Vernon).
  - × *Antedon* ♂ (Godlewski).
- *Strongylocentrotus lividus* ♀
  - × *Arbacia* ♂ (Driesch, Vernon).
  - × *Dorocidaris* ♂ (Köhler, Vernon).
  - × *Echinus* ♂ (Driesch, Vernon).
  - × *Psammechinus* ♂ (Köhler).
  - × *Spatangus* ♂ (Köhler).
  - × *Sphærechinus* ♂ (Hertwig, Köhler, Morgan, Vernon).
- *Strongylocentrotus purpuratus* ♀
  - × *Asterias capitata* ♂ (Loeb).
  - × *Asterias ochracea* ♂ (Hagedoorn, Loeb).
  - × *Asterina* ♂ (Loeb).
  - × *Chlorostoma* ♂ (Loeb).
  - × *Mytilus* ♂ (Kupelwieser).
  - × *Pycnopodia* ♂ (Loeb).
- *Toxopneustes* ♀
  - × *Echinaster* ♂ (Tennent).
  - × *Hipponoë* ♂ (Tennent).
  - × *Holothuria floridana* ♂ (Tennent).
  - × *Mellita* ♂ (Tennent).
  - × *Moira* ♂ (Tennent).

The failure to make a thorough attempt at the determination of the necessary conditions for fertilization by foreign sperm has been due, in my own case, to the fact that it seemed of advantage to make immediate use of the crosses that were readily made and to delay until some future time the investigation of methods necessary for making other crosses.

METHODS OF TREATING ECHINOID EGGS BEFORE FERTILIZATION.

The methods for increasing the number of fertilized eggs in hybrid cultures which have been most employed are: (1) Treatment with alkalis. (2) Treatment with fresh water. (3) Subjection to increased temperature. (4) Excess of sperm. (5) Allowing eggs to stand.

The method of Loeb has been most used, *i.e.*, treatment of the eggs with an alkali before fertilization. This method has been used with signal success by Herbst and Godlewski.

Herbst (1906, p. 183) obtained his best results by adding between one and two drops $\frac{n}{10}$ NaOH to 20 c.c. sea-water, and further pointed out that the optimum concentration is an individual affair.

Doncaster (1903) found that the percentage of fertilizations was increased in diluted sea-water. Herbst (1906) also tried the effect of fresh water, allowing the eggs to remain in fresh water 1 to 3 minutes. Some of the eggs were destroyed, but most remained unharmed by the treatment. As to the value of this method when compared with others mentioned, he does not feel prepared to decide.

Herbst's (1906*a*) experiments on the influence of warmth are of interest. In general it seemed that the optimum was about 24° C.

Born's method of excess of sperm is of somewhat doubtful value when used for Echinoderm crosses. With this method polyspermy is the usual result.

The method used by the Hertwigs (1885), of allowing the eggs to stand for some time before fertilization, has been used by several investigators. Vernon was at first inclined to regard it as a most useful method, but later came to look upon it as of somewhat doubtful value, especially when one desired older larvæ. Driesch also does not regard the method favorably. In my own work it is the method that I have employed almost exclusively and it has given me exceptionally good results. I have found that there is an individual or more properly a species optimum for the length of time that the eggs should stand. For example, with the eggs of *Arbacia*, *Hipponoë*, and *Toxopneustes*, with which most of my work has been done, three different periods of time were allowed to elapse before the eggs were fertilized.

The *Arbacia* eggs were fertilized with *Moira* sperm 7 hours after their removal from the ovary. The *Hipponoë* eggs were best fertilized with *Toxopneustes* sperm 2½ hours after removal from the ovary. The *Toxopneustes* eggs were best fertilized with *Hipponoë* sperm 6 hours and with *Moira* sperm (at Beaufort) 5 hours after removal from the ovary.

I have tried other methods which will be mentioned in other parts of this paper, but never with the success that followed that of allowing the eggs to stand. The percentage of fertilization following this treatment in the *Arbacia*, *Hipponoë*, and *Toxopneustes* crosses was from 75 to 95 per cent.

In another paper (Tennent 1910*a*) I have described in detail the methods that were employed in my work at Beaufort. Similar care was exercised in the work at Tortugas in order to avoid results which might be due to careless laboratory manipulation. All dishes and instruments used were sterilized and especial care to avoid chance fertilization was taken.

AIM OF THE INVESTIGATION.

The aim of the research is the formulation of a statement of the conditions governing the resemblance of the offspring to the parent.

Herbst (1906 *a*, p. 173) has stated the purpose of his investigations simply when he asks the question, "Why do the offspring sometimes stand as a mean between the two parents; why do they sometimes incline more to one or more to the other; or again, why do they resemble one parent completely or almost completely while the characters of the other are repressed?"

We are acquainted to some extent with three types of heredity: (1) Blended heredity. (2) Particulate or Mosaic heredity. (3) Alternative heredity. In the vast amount of research that is being done to-day we lose sight of the fact that this is simply an artificial distinction and that the actual aim of studies of this kind is not the elucidation of one type in particular, but the determination of a "law" of heredity, a statement of the phenomena of inheritance that will be broad enough to include all types.

The study of Echinoderm crosses impresses the fact of the actual singleness of type upon one with peculiar force. In the embryos of one cross we may find all three "types" of heredity exhibited, and yet, so far as we can determine, these embryos have been subjected to the same environment.

How far-reaching this diversity of form may be is impossible to say, for we may make this statement only with respect to the larvæ. No one has yet been able to carry hybrid embryos through their metamorphosis to the adult condition, not to mention the absolutely necessary further step of obtaining individuals of a second generation. This will be a difficult, but probably not an impossible achievement, which will require for its completion the opportunity for working continuously at a marine laboratory for some years.

SURVEY OF OUR PRESENT KNOWLEDGE OF ECHINODERM CROSSES.

The primary stimulus to the investigation of Echinoderm crosses was given by Boveri (1889, 1895) in his effort to determine the localization of the force directing heredity, *i.e.*, to determine whether this force is resident in the nucleus or in the cytoplasm. The Hertwigs had previously seen the entrance of the sperm into enucleated egg fragments and had expressed the opinion that probably nothing would come from such fragments.

Boveri (1895) made the cross between *Echinus microtuberculatus* ♂ and *Sphærechinus granularis* ♀ and obtained an intermediate form (text figs. 1, 2, 3, and 4). He also fertilized fragments of *Sphærechinus* eggs with *Echinus* sperm and obtained hybrids of three kinds: (1) Hybrids of the same size as the ordinary larvæ but intermediate in form. (2) Dwarf larvæ of mixed form. (3) Dwarf larvæ of pure *Echinus* type.

Boveri concluded that the dwarf larvæ of pure *Echinus* type had been derived from the fertilization of enucleated *Sphærechinus* egg fragments and that the experiment showed the lack of cytoplasmic influence.

Seeliger (1894) and Morgan (1895) criticized this conclusion, Seeliger showing that in the *Sphærechinus* ♀ × *Echinus* ♂ cross all of the larvæ were not of an intermediate but that some were of the paternal type, and that in Boveri's experiments dwarf larvæ of the *Echinus* type might have been derived from nucleated fragments. Morgan found that among the crossed larvæ a large percentage showed the pure *Echinus* form. Steinbrück (1902), in his study of *Sphærechinus* ♀ × *Strongylocentrotus* ♂ crosses, concluded that hybrids are not always of a mid-form, but show an extraordinary variability and exhibit a complete series between paternal and maternal form. In my own investigations, in certain circumstances, I have found a complete series and I have found that it is possible, by changing the environment, to increase or decrease the percentage of larvæ resembling one or the other parent.

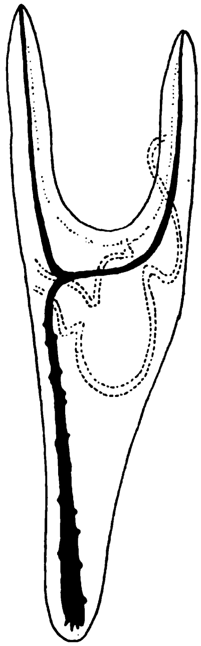

FIG. 1.—Side view of pluteus of *Echinus microtuberculatus* (Boveri).

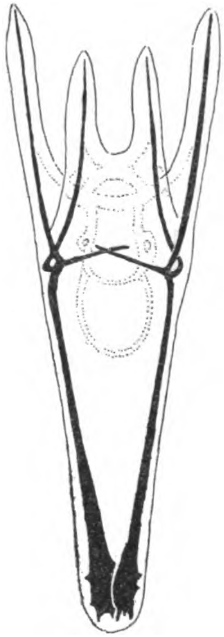

FIG. 2.—Pluteus of *Echinus microtuberculatus* (Boveri).

To Boveri himself, while admitting the validity of the criticisms of his original proposition, must be given the credit of furnishing us with a rational interpretation of these variations, based on cytological studies (Zellen-Studien 5 and 6), and it is on the basis of this interpretation that the more recent work of Herbst, Baltzer, and others is founded.

The beginning of a second phase of work in Echinoderm hybridization was marked by the appearance of Vernon's papers. As a preparation for his work on hybridization, Vernon (1895) made a careful study of the effect of environment on the development of Echinoderm larvæ, using *Strongylocentrotus lividus* as the subject of his research. As means of changing the environment he used (1) Differences in temperature, (2) Differences in concentration of sea-water, (3) Differences in light, (4) Chemical agents.

Strongylocentrotus eggs were placed in water of 8° or 25° C. for an hour, or even for a minute, at the time of impregnation. After 8 days the resulting plutei were 4.4 per cent smaller than those from eggs fertilized at 17° to 22° C. Larvæ allowed to develop in water 17° to 22° C. were 2 per cent or more larger than those allowed to develop at temperatures above or below these limits.

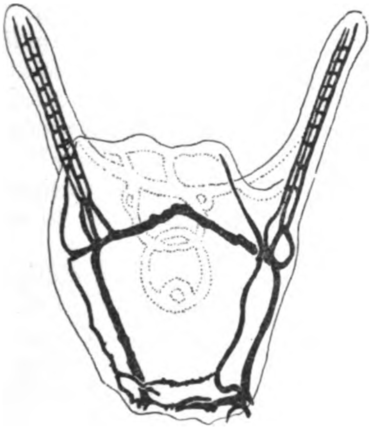

Fig. 3.—Pluteus of *Sphærechinus granularis* (Boveri).

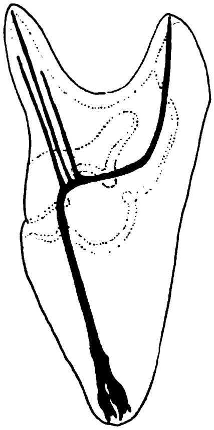

Fig. 4.—Hybrid pluteus *Echinus microtuberculatus* ♂ × *Sphærechinus granularis* ♀ (Boveri).

The normal breeding season of *Strongylocentrotus* is from December to March. Larvæ from fertilizations made in August were 20 per cent smaller than those obtained in April, May, or October. June and July larvæ were intermediate in size—this due to immaturity.

The addition of 50 c.c. distilled water to a liter of sea-water gave larvæ 15.6 per cent larger than larvæ grown under normal conditions; 25 c.c. distilled water to a liter of sea-water, 9.5 per cent larger; 150 c.c. distilled water to a liter of sea-water, 4.3 per cent smaller. Larvæ developed in more concentrated sea-water were unchanged; larvæ grown under normal conditions from impregnations made in concentrated sea-water were 1.6 per cent larger. Larvæ grown in semi-darkness were 2.5 per cent larger; in darkness 1.3 per cent smaller; in blue light (copper sulphate), 4.5 per cent smaller; in violet blue light (Lyons blue), 7.4 per cent smaller; green light, 4.8 per cent smaller; red light, 6.9 per cent smaller; yellow light, 8.9 per cent smaller.

The body length was uninfluenced by the number of larvæ in a given volume of sea-water, provided this number be kept below 30,000 per liter. It was also uninfluenced by the amount of sperm added on impregnation. Larvæ grown in water containing an additional amount of carbonic acid were slightly larger than normal.

The larvæ were not much influenced by partial de-aëration or by oxygenation of the water in which they were developing.

The aboral and oral arms reached their maximum length after 8 days' development, after which they underwent absorption. The body length increased regularly up to the sixteenth day. The arms of larvæ impregnated at 8° were 8 per cent shorter than normal; at 25° about 2.5 per cent shorter. In larvæ developed above 22° the aboral and oral arms were respectively 10.8 per cent and 8.5 per cent longer than those developed at 18° to 20°. The body length of larvæ developed in diluted water was increased on an average by 9.1 per cent, while the arm lengths were increased by 7.7 per cent and 10.5 per cent. The absolute arm lengths were not affected. Arm lengths in darkness, semi-darkness, green and violet lights were 10 per cent or more shorter than those grown under normal conditions.

The variability of larvæ with respect to body lengths declined after the fifth day. The variability reached a maximum at 18° to 20°, the temperature most favorable to development.

In this work Vernon notes the common occurrence of multiple rods in the anal arms, this variation sometimes reaching 35 per cent.

Vernon (1898) determined the specificity of reaction to temperature in *Strongylocentrotus*, *Sphærechinus*, and *Echinus*: The *Strongylocentrotus* pluteus body was largest at 23.7°; the *Sphærechinus* pluteus body at 15.9°; the *Echinus* pluteus body at 20.4°.

Steinbrück's (1902) study of *Strongylocentrotus* showed that the occurrence of multiple rods in the anal arms is a common variation. In a study of *Toxopneustes* (Tennent 1910) I have shown in the purely bred larvæ a type or line variation and the tendency of the eggs of a given female to vary as a whole in some direction. Hagedoorn (1909) has shown the common occurrence of similar variations in the skeleton of *Strongylocentrotus purpuratus*.

Herbert's (1906) research on purely bred larvæ seems to have escaped the attention of most investigators. He subjected embryos *Echinus Sphærechinus* and *Strongylocentrotus* to temperature changes.

For *Echinus* he notes with increased temperature: (1) A striking increase in the number of multiple rods. (2) The average body length at 24° to 25.75° is less than at lower temperature. (3) The average arm length is longer than at lower temperatures. (4) In frequent cases the beginning of lattice formation.

For *Sphærechinus* he notes with increased temperature: (1) An increase of multiple rods. The number of rods may be increased one or two and in infrequent cases from three to six; but the number of rods which reach entirely to the end of the arm is raised only about one.

(2) The average body length at 13° to 14° is greater than at 24° to 26°. (3) The rods are longer than in the cold temperatures. (4) That the number of cross connections in the anal rods increases.

For *Strongylocentrotus* he notes with increased temperature: (1) Plutei at 26° show an increase of multiple rods. (2) The average body length at 24° to 25° is somewhat greater than at 13° to 14°. (3) In infrequent cases the beginning of lattice formation.

SUMMARY OF THE RESEARCHES ON PURE FORMS.

Summary of Vernon's observations.

(1) Multiple anal arm rods sometimes appear in *Strongylocentrotus*.
(2) The optimum temperature for fertilization, 17° to 22° C.
(3) The optimum temperature for growth, 17° to 22° C.
(4) The optimum temperature for arm growth, 17° to 22° C.
(5) The optimum light for growth is ordinary diffuse daylight.
(6) There is a species temperature optimum for *Strongylocentrotus*, *Sphærechinus*, and *Echinus*.

Summary of Herbst's observations.

(1) Increased temperature gives an increase in multiple rods.
(2) There is a species temperature optimum for body size.
(3) In *Strongylocentrotus* and *Echinus*, in a small percentage of cases, lattice formation is caused by increased temperature.

The outcome of these researches has been to show that some of the varieties of skeletal structure found in hybrids may occur as normal variations in purely bred larvæ, and further that such variation may be induced by a change in the external conditions, notably by changes in temperature.

After considering the cross-fertilization results I shall refer again to these observations on purely bred forms, when their importance will be evident.

OBSERVATION ON CROSSES.

Vernon (1898, 1900) working with *Arbacia*, *Dorocidaris*, *Echinocardium cordatum*, *Echinocardium mediterraneum*, *Echinus acutus*, *Echinus microtuberculatus*, *Sphærechinus*, and *Strongylocentrotus*, out of 64 possible direct and cross-fertilizations tried 49. Of these, 29 gave plutei of 8 days' growth, 9 gave segmenting ova, blastulæ, or gastrulæ, and 11 gave no sign of cross-fertilization whatever.

It is in a measure unfortunate that the fine observations of Vernon's earlier paper should be based on body proportions alone. This situation is to some extent relieved by the supplementary and the new observations on the skeletal structures described in the later paper.

Perhaps the most important of Vernon's results was the determination of a seasonal variation in the character of the plutei obtained from the crosses. In general, with *Echinus-Arbacia*, *Echinus-Strongylocentrotus*, *Sphærechinus-Echinus*, and *Sphærechinus-Strongylocentrotus*, *i.e.*, with the most successful crosses, the summer larvæ were of the maternal type, while the autumn and winter larvæ were of the paternal type. Vernon concluded that this variation was due to the relative maturity of eggs and sperm.

Besides this major conclusion, two minor conclusions are of importance:

(1) Respecting reciprocal crosses; 9 out of 13 possible reciprocal crosses were attempted, from which, plutei were obtained from both crosses in 7 instances. Vernon concluded that "The capacity for reciprocal crossing seems, therefore, to be the rule rather than the exception."

(2) Respecting the Hertwigs' conclusion with regard to cross-fertilization and the staleness of the eggs, he confirmed the observations as to fertilization itself, but decided that there was a less tendency for such stale eggs to develop to plutei than for eggs fertilized in a fresh condition.

Herbst (1906, 1907) had little faith in the idea of a greater or lesser ripeness of reproductive elements and sought for another controlling factor. "Das ist aber für unsern Zweck ein erfreuliches Resultat, denn jetzt ist die Möglichkeit vorhanden, dass wir an Stelle des dunklen innern Faktors der verschiedenen Reife einen scharf präzisierbaren äusseren in die Hand bekommen können, von dem die Ausgestaltung der Bastarde abhängig ist," expresses his attitude towards the question. He suggested, as possible means of control, change in temperature, change in salt-content, or change in concentration of OH ions, the last of which might be connected with the presence of larger or smaller quantities of algæ or connected with the reserve-stuff content of the eggs, which would be dependent on variation in the interaction of sea-urchin and environment.

Herbst selected the skeleton as the character for study. In his investigations with *Sphærechinus* ♀ × *Echinus* ♂ and *Sphærechinus* ♀ × *Strongylocentrotus* ♂ he considered in detail the effect of changes in temperature on the character of the skeletal rods of the anal arms and on the number of "roots" of anal arm supports, defining these roots as any outgrowth from the horizontal part of the oral bar, anal crossbar, or body-skeleton directed into the anal arm.

For the purpose of comparing Herbst's results with my own I include parts of four of Herbst's tables, Nos. III, VI, X, and XII (1906, pages 192, 203, 225, 230).

Herbst's Table III $\frac{\text{Str. ♂}}{\text{Sph. ♀}}$	**Temp.** **11° to 19° C.**	**Temp.** **24° to 27° C.**
Number of plutei with lattice structure	19	37
Number of arms with lattice structure	24	53
Number of arms with multiple bars	28	5

Herbst's Table VI. $\frac{\text{Str. ♂}}{\text{Sph. ♀}}$	**Temp.** **11° to 19° C.**	**Temp.** **24° to 27½° C.**
Anal arm rods with 1 root	35	10
Anal arm rods without lattice str	24	5
Anal arm rods with 2 roots	54	54
Anal arm rods with 3 roots	10	27
Anal arm rods with 4 roots	0.6	9

Herbst's Table X. $\frac{\text{Ech. ♂}}{\text{Sph. ♀}}$	**Temp.** **11° to 19° C.**	**Temp.** **23° to 29° C.**
Number of plutei with lattice structure	12	37
Number of arms with lattice structure	19	54
Number of arms with multiple bars	28	15

Herbst's Table XII, $\frac{\text{Ech.} ♂}{\text{Sph.} ♀}$	Temp. 11° to 19° C.	Temp. 23° to 29° C.
Anal arm rods with 1 root	35	6
Anal arm rods without lattice structure	25	3
Anal arm rods with 2 roots	54	36
Anal arm rods with 3 roots	9	38
Anal arm rods with 4 roots	1	11
Anal arm rods with 5 roots	0	7
Anal arm rods with 6 to 7 roots	0	2

It will be seen at once that in temperatures of 23° to 29° C. there is a greater number of plutei and a greater number of arms with lattice structure than in temperatures below 20° C. Similarly the influence of higher temperatures in increasing the number of roots will be noted.

We have already seen the influence of temperature on pure forms. We may now interpret the pure form and cross-fertilization results.

1. *Sphærechinus* ♀ × *Strongylocentrotus* ♂ and *Sphærechinus* ♀ × *Echinus* ♂, through abundance of beginnings of lattice formation and greater number of crossbars, show in the warmth, on an average, more resemblance to the mother than to the father.

2. We can not say that warmth causes this, since in pure *Sphærechinus* larvæ also the number of crossbars is raised in the warmth.

3. Similarly for the anal arm roots, *Sphærechinus* ♀ × *Strongylocentrotus* ♂ warmth plutei are more like the mother than are the cold plutei. We can not make a similar assertion for the *Sphærechinus* ♀ × *Echinus* ♂ plutei.

4. In both combinations it is impossible for us to speak with respect to the number of arm-bar roots, of a proportionally strong resemblance to the mother.

5. Plutei of the *Sphærechinus* ♀ × *Strongylocentrotus* ♂ have body proportions like the mother, but we can not speak of a stronger appearance of maternal body proportions in the higher than in the lower temperatures. With the *Sphærechinus* ♀ × *Echinus* ♂ combination we can not assert even the first.

6. The average body length of the *Sphærechinus* ♀ × *Strongylocentrotus* ♂ hybrids is swung more toward the maternal side in the warmer than in the colder temperatures.

7. We have recognized a second example of such oscillation in the combination *Sphærechinus* ♀ × *Echinus* ♂, where the maternal characters, with respect to body length, become prominent in the cold.

8. In the pairing of sea-urchins with one like character, there may appear in the descendants a weakening of this character.

Herbst's conclusions regarding the influence of temperature at different times are of importance:

1. In order to obtain an increase in fenestrated rods it is immaterial whether we expose the unfertilized eggs, or the blastulæ without mesenchyme, to the higher temperature.

2. It is not sufficient for increasing the number of larvæ with lattice structure, if we expose the germs only temporarily to the warmer temperature and then carry them back. The higher temperature must be

applied throughout the gastrula stage if the number of rods with latticed structure is to be increased.

3. The number of anal arm supports with more than one root is already determined by the gastrula stage, before the triradiate spicules have given rise to rods. In the cultures transferred to warmth at the gastrula stage, there is no such increase in number of arm supports with three or four roots as in warm cultures in which the larvæ remain to the completed pluteus.

Doncaster (1903) concluded that the different hybrids owe their peculiarities to the temperature of the water in which they developed. Herbst's conclusion (1906) is that Vernon's seasonal variation is partly dependent on temperature. Besides this, another unknown factor has played a rôle, this factor varying not only during the time of year but also varying in the two years. Herbst feels himself forced upon the idea of a variation of hybrid form which is certainly not connected with the direct influence of temperature in the formation of the larvæ.

THE CONTROL OF DOMINANCE.

Herbst (1906 *b*) found a method of controlling the appearance of maternal characters in the combination of parthenogenesis and fertilization. By subjecting the eggs of *Sphærechinus* to treatment which would cause their parthenogenetic development and fertilizing them with *Strongylocentrotus* sperm before the nucleus had fairly begun its processes of division, Herbst obtained a displacement of heredity to the maternal side. The method of treatment was much the same as that which I used in a study of the star-fish egg (1906), a method which has also been used by Fischel and by Loeb (1907). The effect of the treatment is shown in the following table; the displacement toward the maternal side (*Sphærechinus*) being well marked.

(Herbst, (1906 *b*), Table I, page 482. Anal arm rods, *Sphærechinus* ♀ × *Strongylocentrotus* ♂. Number of plutei studied in each case 50.)

Treatment of eggs before fertilization.	Condition of nucleus at time of fertilization.	Number of plutei with lattice structure.	Anal arm rods with lattice structure.	Partially *Sphærechinus* rods.	Perfect *Sphærechinus* rods.	Typical *Sphærechinus* plutei.
1. Untreated	Unchanged.	29	38	0	0	0
2. Eight minutes in sea-water + acetic acid.	Indistinct, with halo.	45	82	9	9	0
3. Five minutes in sea-water + acetic acid.	Some indistinct. Some distinct. Nuclei larger than normal.	48	90	9	33	8

Herbst suggested that this displacement might be caused by—

(1) The growth of the maternal nuclear substance.
(2) An alteration in the condition of the cytoplasm.
(3) Or both factors together may influence the displacement.

Pursuing the subject further (1907), he determined the critical stage of displacement. A striking shift takes place when the nucleus at the moment of fertilization has become enlarged, although it need not have reached its maximum size. The most favorable moment for the displacement of the course of heredity coincides with the stage of parthenogenetic development in which the egg nucleus has reached its greatest volume, so that (in part of the eggs) even a giving up of nuclear sap to the cytoplasm may have taken place. If the eggs are fertilized at this moment, resemblance to the mother follows. We may term this the high point for displacement.

Boveri, in his Zellen-Studien 5 and 6, has given us a nomenclature for certain phenomena, which will be found useful:

(1) The pronucleus in the egg = a hemikaryon.
(2) The egg nucleus = a thelykaryon.
(3) The sperm nucleus = an arrhenokaryon.

Thus, all nuclei which arise from isolated egg or sperm nuclei are hemikaryons. The first cleavage nucleus and its descendants are amphikaryons. Through reduction in oögenesis and spermatogenesis hemikaryons arise from the amphikaryons. A normal embryo arising from the fertilized egg is amphikaryotic; one from a fertilized egg without an egg nucleus, *i.e.*, from an enucleated egg, is arrhenokaryotic; one arising from an artificially parthenogenetic egg is thelykaryotic. The two latter are in the same sense hemikaryotic. So we may speak of amphikaryosis, hemikaryosis, etc. If the chromosomes of the first cleavage nucleus have doubled without nuclear division we have a diplokaryon and a diplokaryotic organism. Organisms which have in one region normal nuclei, in another abnormal, containing only the derivatives of an egg nucleus or of a sperm nucleus, are respectively partially-thelykaryotic or partially-arrhenokaryotic.

In Zellen-Studien 6 the nomenclature is slightly changed:

1. Instead of hemikaryon we have monokaryon.
2. A dikaryon or amphikaryon, as before.
3. A trikaryon = one egg nucleus + two sperm nuclei.
4. A diplokaryon = tetrakaryon contains four times the elements of the monokaryon.

Boveri had shown (Zellen-Studien 5) that the surface of the nuclei of the somatic cells of the sea-urchin is directly proportional to the number of chromosomes in the developing egg. Marcus (1906) had shown the relation between temperature and nuclear size. With this knowledge, Herbst proceeded to ascertain the fate of the sperm nuclei in hybrids with altered heredity. He reasoned that if one compared nuclei of parthenogenetic larvæ with those of normal larvæ and with those of larvæ having had the double treatment, the earlier nuclei of the former, having half as many chromosomes, should have half as great a nuclear surface as those of normally fertilized eggs, and therefore the same should be true when compared with the nuclei of doubly treated eggs. The matter, however, was not so simple. The study of the nuclei of the ciliated bands and the body parts of 28 parthenogenetic larvæ gave no half nuclei. The nuclei were either of normal size or were above normal size. This leads to the conclusion that there must have been many cases of monaster formation.

Notwithstanding this complication, the comparison of the nuclear size of purely parthenogenetic larvæ with those of hybrids with displaced heredity proved of value. Herbst succeeded in fitting the larvæ that he obtained to the types suggested by Boveri and in demonstrating the actual participation of the sperm nucleus in the activities of fertilization and of segmentation.

Herbst first made a study of the nuclear size of parthenogenetic larvæ. He found:

1. Diplothelykaryotic larvæ. This was the most numerous form. They may have arisen from a single monaster formation of a Monokaryon (hemikaryon).

2. Tetrathelykaryotic larvæ. These may have arisen by two monaster divisions; they have very large nuclei.

3. Larvæ with nuclei intermediate in size between (1) and (2). These may have arisen,

(*a*) From eggs of over-normal nuclei. These nuclei may have arisen from one monaster division; they would be diplothelykaryotic.

(*b*) From eggs of under-normal nuclei. These nuclei may have arisen from two monaster divisions. They would be tetrathelykaryotic.

(*c*) From eggs of normal nuclei. These nuclei may have arisen from two monaster divisions, but in this monaster formation some of the chromosomes must have remained undivided.

Proof of the copulation of egg and sperm nuclei was drawn from the occurrence of partially-thelykaryotic larvæ. In such larvæ (see Herbst 1907, figs. 3 and 4) the skeleton of the anal arms is of the *Sphærechinus* type on one side and of the hybrid type on the other. This condition may be due to the fact that the chromatic matter of the maternal and paternal nuclei separated in the first division. A slight difference between the two sides may be due to the influence of cytoplasm given off by the male nucleus. Some indication of paternal influence may be seen even in the maternal half. On the hybrid side of the pluteus, large nuclei are found; on the maternal side small nuclei.

A comparison of other larvæ of the cultures was made with these partially-thelykaryotic larvæ, *i.e.*, a comparison of nuclei was made. Herbst reasoned that if he found larvæ whose nuclei corresponded in size with those of the hybrid side of the partially-thelykaryotic larvæ, he would be at liberty to conclude that in these cases a copulation of the two sex nuclei had taken place. If he found, on the contrary, small nuclei, he must conclude that in these the copulation had not taken place and that he had hemikaryotic plutei.

(1) Hybrids with large nuclei; maternally directed heredity (Herbst's figs. 6 and 7): These larvæ were of a pronounced maternal type. Their nuclei are large, like those of the hybrid half of partially-thelykaryotic larvæ.

(2) Hybrids with small nuclei; from cultures with maternally directed heredity: Out of 79 larvæ, there were 11 with small nuclei. A comparison with other nuclei shows that these are typical half nuclei. We may distinguish two types of plutei of this class:

(*a*) Plutei of the maternal type with small nuclei: A pluteus of this type is shown in Herbst's (1907) fig. 10. Here only the female nuclei have taken part in the development. The probable explanation of this condition is that it is a case of partial fertilization and subsequent separation of the two nuclei. In this event it must be acknowledged that the sperm has been of some influence before its elimination.

(*b*) Plutei of the paternal type with small nuclei: A pluteus of this type is shown in Herbst's (1907) fig. 14. This is a typical arrhenokaryotic pluteus, but shows evidences of its hybrid origin. The nuclei must be designated as half nuclei. When regarded in the light of Boveri's (1889, 1895) suggestion, to which we have already referred, it will be seen that we have here larvæ with only paternal nuclear material which shows hybrid characters. These larvæ are more properly partially-arrhenokaryotic plutei. They have arisen from multiple fertilization.

Displacement of heredity toward the maternal side occurs in many ways. It is not essential that the processes of fertilization be modified from the beginning. In some cases it is a delay of fertilization, *i. e.*, of copulation of egg and sperm nucleus, that is responsible for the displacement. This delay may have various consequences:

(1) It may lead to a failure of the sex nuclei to unite and in some way to an elimination of the sperm. Thus half nuclei may originate and give us wholly or nearly pure *Sphærechinus* plutei in the cultures with maternally directed heredity.

(2) It may lead to copulation after the egg nucleus has completed the first steps of division. According as this is a dyaster or a monaster, we may have two subdivisions;

(*a*) The sperm nucleus may copulate with one of the two cleavage nuclei. From such eggs partially-thelykaryotic larvæ may arise. These larvæ are found infrequently.

(*b*) The sperm nucleus may copulate with the egg nucleus after the latter has reached a double size through monaster formation. Monasters are common, so this case is not infrequent. It is to be expected when a halo is present around the nucleus at the moment of fertilization. There are probably other possibilities in methods of displacement. Herbst believes that the cause of displacement lies in an altered ratio of egg nuclear and sperm nuclear size. If the egg nuclear substance be in excess, then there will be a preponderance of maternal characters, while if the sperm nuclear substance be in excess there will be a preponderance of paternal characters in the descendants.

Because of the great importance of this (1907) paper I give a brief summary of Herbst's conclusions.

(1) The critical stage for displacement occurs when the egg nucleus at the moment of fertilization has shown a distinct increase in size.

(2) There is a difference in intensity of displacement corresponding with the stage at which fertilization takes place; the maximum displacement coinciding with the greatest expansion of the egg nucleus before its solution. After the passing of the maximum size there is a gradual falling of displacement, but not to zero.

(3) Larvæ with maternally directed heredity, as a rule, have larger nuclei than the ordinary hybrids of the same culture.

(4) The hybrids with nuclei larger than the normal may have arisen by copulation of a diplothelykaryon and an arrhenokaryon.

(5) Partially-thelykaryotic larvæ may arise when the sperm nucleus copulates with one of the daughter nuclei succeeding dyaster formation.

(6) Hybrids of the maternal type with small nuclei may have arisen because of the elimination of male nuclear material.

(7) Hybrids of the paternal type with small nuclei are probably arrhenokaryotic, the maternal nuclear material having been eliminated.

(8) Hybrids may be partially arrhenokaryotic in character.

(9) Displacement to the maternal side may be caused in various ways.

(10) The course of heredity may depend on relative proportion of female nuclear mass.

NEW INVESTIGATIONS.

There is, as is well known, a characteristic period of time between fertilization and the appearance of the first cleavage furrow. I bring these statistics together in this place for the sake of comparison. Fertilizations were made at temperatures varying between 26° and 31° C. *Arbacia*, 40 to 47 minutes; *Hipponoë*, 60 to 75 minutes; *Mellita*, 30 to 60 minutes, usually 35 minutes; *Moira*, 35 minutes; *Toxopneustes*, 37 to 45 minutes. These variations are not altogether correlated with differences in temperature.

DESCRIPTION OF NORMAL PLUTEI.

One is much impressed by the more rapid earlier development of the forms considered in this paper than of the forms described by European investigators. The following outline of the normal development of one series of *Toxopneustes* eggs may be of interest.

(Fertilization made at $12^{h}40^{m}$ p. m. Temperature of water, 28° C.)

First cleavage	$1^{h}20^{m}$	meridional	2 cells.
Second cleavage	$1^{h}50^{m}$	meridional	4 cells.
Third cleavage	$2^{h}15^{m}$	horizontal	8 cells.
Fourth cleavage	$2^{h}30^{m}$	horizontal (micromeres)	12 cells.
Fifth cleavage	$2^{h}30^{m}$	meridional of upper 4	16 cells.
Sixth cleavage	$2^{h}50^{m}$	meridional of lower 4	20 cells.
Seventh cleavage	$2^{h}50^{m}$	meridional of upper 8	28 cells.
Eighth cleavage	$3^{h}00^{m}$	horizontal (mic. to form second set)	32 cells.
Ninth cleavage	$3^{h}15^{m}$	horizontal (div. of lower 8)	40 cells.
Tenth cleavage	$3^{h}35^{m}$	meridional (up. 16 to 32)	56 cells.
Eleventh cleavage	$3^{h}35^{m}$	meridional (next 8 to 16)	64 cells.
Twelfth cleavage	$3^{h}45^{m}$	meridional (first mic. to 8)	68 cells.
Thirteenth cleavage	$3^{h}50^{m}$	meridional (lower 8 to 16)	76 cells.

Fourteenth cleavage.....	$4^{h}00^{m}$	meridional (second 16 of eleventh to 32) 92 cells.
Fifteenth cleavage......	$4^{h}30^{m}$	meridional (upper 32 of tenth to 64) 124 cells.
	$5^{h}45^{m}$	Blastulæ rotating within membrane.
	$6^{h}00^{m}$	Membrane thrown off. Blastulæ swim.
	$6^{h}30^{m}$	Most swimming at surface.
	$8^{h}25^{m}$	Mesenchyme formation beginning, 4 cells in blastocoel.
	$9^{h}25^{m}$	Beginning gastrulation.
	$3^{h}00^{m}$	a.m. Pigment spots and skeleton beginning.
	$12^{h}00^{m}$	noon. Many plutei with anal arms.

The explanation of this more rapid development may be found in the differences in temperature between the localities in which the work has been done.

In hybridization work it is desirable to cross forms whose plutei possess striking structural differences. The most advantageous Echinoid crosses upon which any detailed work has been done by the European investigators are the *Sphærechinus* × *Strongylocentrotus* and the *Sphærechinus* × *Echinus* combinations. These are advantageous because the *Echinus* and *Strongylocentrotus* anal arm skeletons consist of a single, slender rod, while the *Sphærechinus* anal arm skeleton is of the fenestrated type, being made up of three rods united with one another by crossbars. The same advantage is afforded by American crosses in which one of the forms used is *Toxopneustes*. The plutei of *Toxopneustes* have a single rod as the support in the anal arms. The plutei of *Arbacia, Hipponoë, Mellita,* and *Moira* have anal arm skeletons of the latticed type.

In my observations, then, *Toxopneustes* will correspond to *Echinus* (text figs. 1 and 2) and *Strongylocentrotus* (text fig. 7), while *Arbacia, Hipponoë, Mellita,* and *Moira* will correspond to *Sphærechinus* (text figs. 3 and 6).

ARBACIA.

The normal *Arbacia* pluteus (plate 1, fig. 8) is distinctly pyramidal in form. The skeleton (plate 1, fig. 9) is rather heavily formed, the body skeleton terminating in an irregular club-like enlargement. The supports of the anal arms are of the ladder-like type. I have not succeeded in keeping *Arbacia* plutei alive in laboratory cultures for more than ten days. The older plutei and young adults which have just completed their metamorphosis are readily obtained in surface towings.

HIPPONOE.

In the *Hipponoë* pluteus (plate 1, figs. 3 and 4) the posterior end of the body is truncated. The anal arm rods are fenestrated. The oral arm rods are continued posteriorly as the dorsal body skeleton and unite with the ventral body skeleton to form a basket. All of the rods are heavy in character. These plutei live well in laboratory cultures.

MELLITA.

The *Mellita* pluteus (plate 1, figs. 10, 11, and 12) is rounded posteriorly. The oral arm rods are continued posteriorly as the dorsal body skeleton and unite with the ventral body skeleton to form a complicated basket. The anal arm rods are fenestrated.

MOIRA.

The *Moira* pluteus (plate 1, figs. 5, 6, and 7) in the older stages is characterized by the possession of a posterior unpaired spine whose method of origin is shown in plate 1, fig. 5. The anal arm rods are fenestrated.

TOXOPNEUSTES.

The *Toxopneustes* pluteus (plate 1, figs. 1 and 2) is more slender in form than the others considered. It differs from them further in that the skeletal rods of the anal arms are single, slender rods whose surface is roughened by the presence of thorn-like projections. The dorsal and ventral body skeletons are not connected posteriorly. A detailed consideration of these plutei of various ages may be found in my paper on variation in *Toxopneustes* plutei (Tennent 1910).

THE CROSSES.

ARBACIA:

Two crosses with the *Arbacia* egg were made, one with *Mellita* and one with *Moira.* A fertilization membrane was formed. In both instances cleavage took place about 40 minutes after fertilization, the time of beginning of cleavage thus not being changed by the use of foreign sperm. The *Arbacia* egg is small and deeply pigmented, and is not adapted for study of the nuclear activities in the living conditions. I have shown elsewhere (1908) that the preserved egg is especially favorable for the study of chromosomes in cross-fertilized eggs.

ARBACIA ♀ × MELLITA ♂:

The greater number of plutei obtained from the *Arbacia* ♀ × *Mellita* ♂ cross (plate 2, fig. 22) could be referred neither to the maternal nor to the paternal type. In most cases the skeleton of the anal arms consisted of from two to four unconnected or irregularly connected rods. No plutei of a pronounced paternal type were found. The posterior basket was undeveloped. About 2 per cent were of the maternal type shown in plate 2, fig. 22, although here the hybrid characters of the larvæ are at once evident. The plutei are not intermediate in type, but form a series. The body is in general of the *Arbacia* type.

ARBACIA ♀ × MOIRA ♂:

The *Arbacia* ♀ × *Moira* ♂ cross was readily made and was very successful for segmentation, but was of little use in the older stages. The eggs were allowed to stand for 7 hours and were then fertilized with active *Moira* sperm. The hybrids were irregularly intermediate in character. No trace of a posterior unpaired spine could be seen. The hybrids inclined somewhat to the maternal form, yet showed distinctly their hybrid origin.

TOXOPNEUSTES:

It will be remembered that the *Toxopneustes* plutei are distinctive in form, in that they alone have single rods in the anal arms. The plutei of all other forms worked with have fenestrated rods. Any cross with

Toxopneustes is therefore of especial value. The favorable nature of the *Toxopneustes* egg for the observations of nuclear phenomena during the living stage has been mentioned by other investigators. It has been possible to see, in this egg, the fusion of the pronuclei and to convince myself that the processes of fertilization were being completed.

TOXOPNEUSTES ♀ × HIPPONOË ♂:

This and the reciprocal cross *Hipponoë* ♀ × *Toxopneustes* ♂ are the ones that have made the experimental portion of my work possible. The *Toxopneustes* eggs were fertilized 6 hours after their removal from the ovary, a series of fertilizations showing that the highest percentage of fertilizations was obtained if the eggs were allowed to remain in sea-water for this length of time. A fertilization membrane was formed. Cleavage began 40 minutes after fertilization, this being the period characteristic of the egg.

The character of the hybrids resulting from this cross is shown in plate 2, figs. 27, 29 to 31, plate 3, figs. 32 to 37, and plate 5, figs. 75 to 76. With the exception of the individual shown in plate 3, fig. 32, a pronounced *Hipponoë* dominance is shown. This dominance is expressed in the great number of fenestrated anal arm rods, in the number of multiple rods, and in the general form of the body skeleton. In the fertilizations made in 1910 the *Hipponoë* dominance was further expressed in the occurrence of the basket-like structure at the posterior end of the body. The best idea of the amount of inclination to the paternal type is shown in table I.

TABLE I.—*Summary of results of cross-fertilization in ordinary sea-water.*

[Number of plutei studied, 50. Temperature of water, 28.5° C.]

Year.	Cross.	Plutei with lattice structure.	Anal arm rods with lattice structure.	Arms more than one rod.	Perfect *Hipponoë* rods.	Perfect *Toxopneustes* rods.	Perfect *Toxopneustes* plutei.	Perfect *Hipponoë* plutei.	Basket.
1909	*Hip.* ♂ *Tox.* ♀	33	60	39	14	1	0	5	10
1910	*Hip.* ♂ *Tox.* ♀	24	32	60	0	8	0	0	25

EXPLANATIONS OF HEADINGS OF THE COLUMNS.

"Plutei with lattice structure" are plutei which have parallel rods connected by crossbars in one or both anal arms.

"Anal arm rods with lattice structure" designates the total number of anal arms of the plutei considered in the preceding columns, which have a skeleton composed of parallel rods connected by crossbars.

"Arms more than one rod" indicates an anal arm skeleton of more than one straight rod.

"Perfect *Hipponoë* rods" are anal arm rods which are as perfect as those found in purely bred *Hipponoë* plutei.

"Perfect *Toxopneustes* rods" indicates a single straight rod with thorn-like protuberances.

"Perfect *Toxopneustes* plutei" and "Perfect *Hipponoë* plutei" indicate respectively plutei of the normal *Toxopneustes* and *Hipponoë* type.

"Basket" indicates the basket-like structures present in the posterior part of the body of purely bred *Hipponoë* plutei.

In this examination, in 66 per cent of the plutei studied, arms with latticed structure were found; no perfect *Toxopneustes* plutei, and 5 perfect *Hipponoë* plutei were seen.

In the study of the same cross made in 1910 there were 50 plutei examined, 48 per cent of which had the latticed structure and 50 per cent basket structure.

TOXOPNEUSTES ♀ × MELLITA ♂:

The *Toxopneustes* ♀ × *Mellita* ♂ cross was made after the eggs had stood in sea-water for 5 hours. A fertilization membrane was formed. The fertilization-cleavage period was characteristic of the egg. Most of the larvæ obtained were of the mixed type. In general the hybrids were of the maternal type in body form, but without exception had multiple rods in the anal arms. A few larvæ, such as those shown in plate 2, fig. 21, resemble the plutei of the pure maternal form, although the hybrid origin was very evident. The body skeleton was of the *Mellita* type, but without the posterior basket, and a very abnormal fenestration of the anal arm skeleton was evident. Some of the *Toxopneustes* ♀ × *Mellita* ♂ hybrids were kept alive for upwards of 10 days.

TOXOPNEUSTES ♀ × MOIRA ♂:

This cross was readily made after the *Toxopneustes* eggs had stood in water for 5 hours, experiments showing that the best results were obtained after the eggs were allowed to stand for this length of time. A fertilization membrane was formed. Cleavage took place in about 40 minutes after fertilization; the fertilization-cleavage period being that characteristic of the egg.

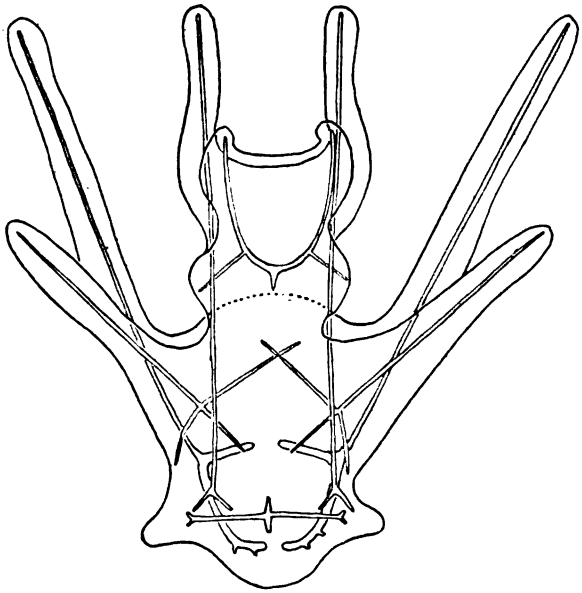

FIG. 5.—Pluteus *Moira* ♂ × *Toxopneustes* ♀.

The greater number of hybrids of this cross were of the intermediate maternal type (plate 1, figs. 13 to 17; plate 2, figs. 18 to 20) having multiple rods in the anal arms. All of the plutei obtained in 1907 were of this character. From two crosses made in 1908, a small percentage, about 1 per cent, of hybrids of a purely maternal form were obtained (plate 2, figs. 18 to 20 and text fig. 5). These showed no trace of their hybrid origin, their perfect form suggesting that they were pure *Toxopneustes* larvæ which had arisen from chance fertilizations. This possibility, I believe, is excluded by the extraordinary care that was taken in making the fertilizations and by the care that was exercised in avoiding contamination while the larvæ were being reared. Herbst and Vernon also obtained similar larvæ of a striking maternal form.

The pluteus shown in plate 2, fig. 20, resembles in all respects a purely bred pluteus of the same age, the epaulets, Echinoderm rudiment, and the first pedicellariæ being well developed. I was not able to obtain adults from any of these plutei, although during the same season I carried laboratory fertilized *Toxopneustes* embryos through their metamorphosis. At the end of 45 days in one instance with the crosses I had 9 and in another 6 plutei in good condition. Upon trying to find them on the succeeding day nothing could be made out, although a careful search of the diatom mud in the bottom of the culture dish was made.

TOXOPNEUSTES ♀ × ECHINASTER ♂:

The result of this cross was not especially noteworthy. No fertilizations were obtained after the usual method of allowing the *Toxopneustes* eggs to stand 5 hours before treatment with sperm. In a second attempt the eggs were exposed to the action of CO_2 sea-water for from 1½ to 10 minutes, and later fertilized after the method that I described five years ago (Tennent 1906). The most successful lot was that treated with CO_2 for 4 minutes. Inasmuch as segmentation did not begin until 2 hours after fertilization, I believe that the fertilization was ineffective and that the segmentation was parthenogenetic. A third attempt at this cross, when I again used the CO_2 treatment, exposing the eggs to the action of CO_2 sea-water for 4 minutes and fertilizing with *Echinaster* sperm 10 minutes after the egg had been transferred to sea-water, resulted in the occurrence of segmentation 55 minutes after fertilization. Cleavage was irregular and the "embryos" obtained were formless, ciliated clumps of cells.

TOXOPNEUSTES ♀ × HOLOTHURIA FLORIDANA ♂:

(1) The *Toxopneustes* eggs were allowed to stand for 2 hours and were then fertilized with *Holothuria* sperm. A fertilization membrane was formed at once. A small percentage of segmentation was obtained.

(2) *Toxopneustes* eggs were treated with $MgCl_2$ (1 c.c. to 100 c.c. sea-water) for 3 minutes. Segmentation began 45 minutes after fertilization with *Holothuria* sperm.

(3) Toxopneustes eggs treated with CO_2 for 4 minutes and fertilized with *Holothuria* sperm 50 minutes after transference to sea-water.

Good fertilization membranes were formed. A high percentage of cleavage was obtained, but the cleavage was irregular.

(4) *Toxopneustes* eggs treated with $\frac{n}{10}$ NaOH (2 c.c. to 100 c.c. sea-water) for 3 minutes and then fertilized with *Holothuria* sperm. Most of the eggs were destroyed by the entrance of the sperm.

(5) *Toxopneustes* eggs treated with $\frac{5}{8}$m $CaCl_2$ (2 c.c. to 100 c.c. sea-water) for 5 minutes and fertilized with *Holothuria* sperm 45 minutes after transference to sea-water. A fertilization membrane was formed at once. Most of the eggs then burst. A few gave good segmentation.

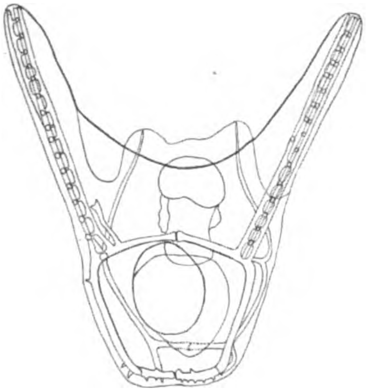

Fig. 6.—Parthenogenetic *Sphærechinus* pluteus (Herbst).

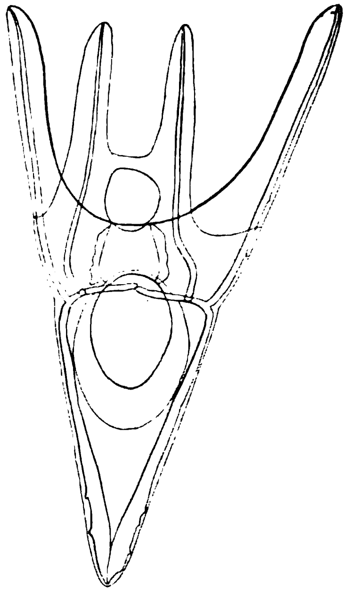

Fig. 7.—*Strongylocentrotus* pluteus (Herbst).

In the eggs treated with $\frac{5}{8}$m $CaCl_2$ and with $\frac{n}{10}$ NaOH the sperm upon entering, in most cases, tears the egg to pieces. A deep notch or pathway made by the sperm may be seen and then the egg suddenly disintegrates. In this connection it is interesting to note that the *Holothuria floridana* egg has a very thick membrane and a well-defined micropyle.

MELLITA:

The *Mellita* ♀ × *Moira* ♂ cross was easily made. About 10 per cent of the eggs were fertilized after being well washed in sea-water. Most of the plutei were of the intermediate maternal type with multiple rods in the anal arm. A few were of a well-marked maternal form (plate 2, fig. 23), yet showing evidences of the hybrid origin. The body was rounded posteriorly, but the skeletal basket was absent. There was no trace of the posterior unpaired spine, the *Moira* character which it was hoped would appear.

MOIRA :

MOIRA ♀ × TOXOPNEUSTES ♂:

This cross was easily made by fertilizing the eggs immediately after they were removed from the ovary. For information regarding the method of obtaining the eggs I am indebted to Dr. Bartgis McGlone, who has also furnished me with two drawings of the *Moira* pluteus, which I have used in this paper. The *Moira* egg is beautifully transparent and well suited for study in the living condition. A fertilization membrane was formed. The copulation of the pronuclei could be observed. Segmentation began 35 minutes after fertilization, as in the straight fertilization. The crosses were of the intermediate type (plate 2, figs. 24, 25, 26). No trace of the maternal posterior, unpaired spine appeared, although the larvæ were kept alive for 7 days.

HIPPONOË (TRIPNEUSTES):

The *Hipponoë* egg, like the *Arbacia* egg, is not well adapted for study in the living state. The egg is small and dark in color. In comparison with the *Toxopneustes* egg it measures in micrometer eye-piece units, Ocular 2 Objective D, *Hipponoë* 19 × 19; *Toxopneustes* 26 × 25.

HIPPONOË ♀ × TOXOPNEUSTES ♂:

The *Hipponoë* ♀ × *Toxopneustes* ♂ cross was the most successful cross made with the *Hipponoë* egg. A series of experiments showed that the largest percentage of fertilizations was obtained when the eggs were fertilized 2½ hours after their removal from the ovary. During the work of 1909 the cleavage began 75 minutes after fertilization, as in the normally fertilized egg. In the experiments of 1910, although the fertilization-cleavage period in the normally fertilized eggs remained the same, cleavage in the cross-fertilized eggs began in 55 minutes, a reduction of 20 minutes. No fertilization membrane was ever obtained, the only membrane formed being the "Verbindungs-membran." In the plutei of this cross (plate 2, fig. 28; plate 3, figs. 38 to 43), there is a pronounced *Hipponoë* dominance as expressed in the skeleton of the anal arm. In the experiments of 1910 the third rod of the skeleton was never developed. The plutei live well in laboratory cultures.

TABLE II.—*Summary of results of cross-fertilization in ordinary sea-water.*

[Number of plutei studied, 50. Temperature of water, 28.5° C.]

Cross.	Plutei with lattice structure.	Anal arm rods with lattice structure.	Arms more than one rod.	Perfect *Hipponoë* rods.	Perfect *Toxopneustes* rods.	Perfect *Toxopneustes* plutei.	Perfect *Hipponoë* plutei.
Tox. ♂ / *Hip.* ♀	37	58	40	30	2	0	12

It will be seen from the table that 74 per cent of the plutei have anal arms with rods having latticed structure. The normal sea-water fertilizations of 1910 were in accord with those of 1909. A count of 50 plutei made in 1910 gave results approximately the same as those of 1909.

HIPPONOË ♀ × CIDARIS ♂:

Hipponoë eggs were fertilized with *Cidaris* sperm 3 hours after their removal from the ovary. No fertilization membrane was formed. The fertilization-cleavage period was characteristic of the egg; segmentation very irregular; larvæ all of abnormal form.

HIPPONOË ♀ × OPHIOCOMA ♂:

Hipponoë eggs were fertilized with *Ophiocoma* sperm 3 hours after their removal from the ovary. No fertilization membrane was formed. The fertilization-cleavage period was characteristic of the egg. All larvæ abnormal.

HIPPONOË ♀ × PENTACEROS ♂:

Hipponoë eggs were fertilized with *Pentaceros* sperm 3 hours after their removal from the ovary. No fertilization membrane was formed. The fertilization-cleavage period was characteristic of the egg; the segmentation and larvæ irregular.

THE EXPERIMENTAL CONTROL OF DOMINANCE.

One of the most interesting and important problems connected with the results of Echinoderm hybridization is the determination of the factors influencing the appearance of maternal or of paternal characters in the hybrid embryo.

We have seen that Vernon (1898, 1900) showed a seasonal variation and tried to show that the characters of the hybrid pluteus are dependent on the relative ripeness of the sperm used in the crosses. Doncaster (1904) concluded, as a result of his experiments, that the temperature of the water in which the embryos developed is the determining factor. Herbst (1906*a*, 1906*b*, 1907), in an extended and able series of papers, expressed his conviction that while temperature was a contributing factor it was not the only one, and showed that the dominance might be swung toward the maternal side by a combination of artificial parthenogenesis and fertilization; the actual cause of this displacement lying in the preponderance of maternal nuclear material arising from the application of this method.

My own investigations have shed further light upon this unknown factor. My experimental evidence shows that while the theories of the investigators mentioned are correct, they do not present the whole truth. My material has been especially fortunate in that I have obtained a dominance of one species over another in both crosses. That is, when the fertilization was made in normal sea-water *Hipponoë* characters were dominant. By changing the conditions in which fertilizations were made I have been able to change this dominance and to show that the actual factor determining the dominance is directly concerned with differences of season and of temperature, but that these two factors are simply contributory.

In my experiments, *the factor determining the dominance is the variation in alkalinity of the sea-water in which the embryos develop.* This variation is probably dependent on season and temperature.

I know of no analyses of sea-water which show a variation, toward or away from neutrality, correlated with change of season and of temperature. We have evidence that sea-water in different localities shows a variation in reaction during the same season. It is merely a matter of speculation, then, when I suggest that the artificial conditions that I produced, which enabled me to control dominance at will, correspond to natural conditions at different seasons of the year.

Algæ, growing in the sea-water, are credited by Loeb (1906) with causing it to become alkaline. It would seem in general that with the higher temperatures of the summer months there would be an increased solution of phosphates and of carbonates to which the alkaline reaction may be due. Whatever the explanation may be, the results of my experiments show a definite effect of a change in environment on the character of the embryos, an effect due to the decrease in the concentration of OH ions, brought about by adding an acid to the sea-water.

The two crosses made which have served as the basis for this experimental work are *Hipponoë* ♀ × *Toxopneustes* ♂ and the reciprocal cross *Toxopneustes* ♀ × *Hipponoë* ♂. Both of these crosses gave plutei with *Hipponoë* characters. It will be recalled that the pure plutei differ from one another in that the *Hipponoë* plutei have anal arm skeletons of the fenestrated type and that a basket-like structure is present at the posterior end of the body, while the *Toxopneustes* plutei have simple rods as skeletons of the anal arms and no basket-like structure is present in the body.

In my presentation of the evidence of *Hipponoë* dominance, I shall confine myself closely to the evidence afforded by a comparative study of the skeletal characters of the purely bred and of the hybrid plutei. From a prolonged study of pure *Toxopneustes* plutei (1910), I am convinced that characters such as the form of the larvæ, in nearly similar forms, the number, pigment-content, and arrangement of the chromatophores, and comparative measurements of parts of the body, are of too variable a nature to afford safe criteria upon which to base conclusions of importance.

I shall regard the presence of more than one rod in the anal arm and the presence of a basket-like structure in the posterior part of the body as an indication of *Hipponoë* influence.

It may be urged that the intraspecific variation of the skeleton is so great that I have no right to use any part of the skeleton as the basis for the conclusions that I am making. We have seen that both Vernon (1898) and Steinbrück (1902) observed the occurrence of multiple rods in the anal arms of *Strongylocentrotus* plutei as a common variation. In my own investigations on *Toxopneustes* (in which cultures from some hundreds of individuals and measurements involving the careful examination of several thousand plutei were made) such a variation was found in the embryo from the eggs of but two individuals. In one case it was found in 1 per cent and in the other in 3 per cent of the plutei examined. In other crosses it occurred as occasional variation. The pure cultures made in 1909 and 1910 as controls for the hybridization experiment showed an occasional pluteus with this variation, but the number was never great enough to exclude the advisability of considering the common appearance of more than one rod, a *Hipponoë* character, as an indication of *Hipponoë* influence.

THE EFFECT OF THE INCREASE IN THE ALKALINITY OF THE SEA-WATER.

With an increase of alkalinity of the sea-water, brought about by the addition of $\frac{n}{10}$ NaOH, the plutei obtained were of the *Hipponoë* type, the increased alkalinity causing little modification. A slight increase of *Hipponoë* influence is apparent.

A series of experiments for determining the effect of varying degrees of increase in alkalinity was carried out. I give one table (Table III) showing the effect of the addition of 20 drops $\frac{n}{10}$ NaOH (1 drop $= \frac{1}{18}$ c.c.) to 400 c.c. of ordinary sea-water. The eggs from which the plutei were obtained were placed, immediately after being removed from the ovary and washed, in the sea-water whose alkalinity had been raised. The *Hipponoë* eggs were fertilized 2½ hours later, in a similar solution, with *Toxopneustes* sperm. The *Toxopneustes* eggs were allowed to remain in a like solution for 6 hours and fertilized with *Hipponoë* sperm.

After fertilization the eggs were changed to more of the same solution, in which they were kept until it was possible to pour the swimming blastulæ into ordinary sea-water, which was changed from time to time during the days through which the investigation was in progress.

TABLE III.—*Summary of results of cross-fertilization in sea-water of increased alkalinity.*

[Number of plutei studied, 50. Temperature of water, 29° C.]

Year.	Cross.	Plutei with lattice structures.	Anal arm rods with lattice structure.	Arms more than one rod.	Perfect *Hipponoë* rods.	Perfect *Toxopneustes* rods.	Perfect *Toxopneustes* plutei.	Perfect *Hipponoë* plutei.
1909	*Hip.* ♂ *Tox.* ♀	39	57[1]	40	15	2	0	3
1909	*Tox.* ♂ *Hip.* ♀	40	62	38	31	0	0	10

Figures of the skeletons of the *Toxopneustes* ♀ × *Hipponoë* ♂ cross which had been subjected to the NaOH treatment are shown (plates 2 and 3, figs. 29 to 37; plate 6, fig. 94); of the *Hipponoë* ♀ × *Toxopneustes* ♂ cross (38–43). The experiments of 1910 showed no change as the result of the increase in alkalinity. This is due, I believe, to the greater alkalinity of the sea-water over that of the previous summer.

THE EFFECT OF A DECREASE IN THE ALKALINITY OF THE SEA-WATER.

With a decreased alkalinity brought about by the addition of $\frac{n}{10}$ acetic or $\frac{n}{10}$ hydrochloric acid, the plutei obtained showed the effect of an influence tending to swing them toward the *Toxopneustes* type. The plutei whose skeletons are shown in the figures were taken at random, no attempt being made to select plutei which would support any theory. (See *Toxopneustes* ♀ × *Hipponoë* ♂, figs. 44–85, and *Hipponoë* ♀ × *Toxopneustes* ♂, figs. 86–93.)

Table IV gives a summary of results obtained with the acetic acid.

TABLE IV.—*Summary of results of cross-fertilization in sea-water of decreased alkalinity, acetic acid.*

[Number of plutei studied in each fertilization, 50. Temperature, 29° C.]

Year.	Cross.	Plutei with lattice structure.	Anal arm rods with lattice structure.	Arms more than one rod.	Perfect *Hipponoë* rods.	Perfect *Toxopneustes* rods.	Perfect *Toxopneustes* plutei.	Perfect *Hipponoë* plutei.	Basket.
1909	*Hip.* ♂ / *Tox.* ♀	7	7	62	1	31	7	0	–
(1) 1910	*Hip.* ♂ / *Tox.* ♀	4	5	93	0	2	0	0	7
(2) 1910	*Hip.* ♂ / *Tox.* ♀	14	16	81	0	3	0	0	10
(3) 1910	*Hip.* ♂ / *Tox.* ♀	13	15	69	0	16	3	0	12
(4) 1910	*Hip.* ♂ / *Tox.* ♀	3	5	51	0	44	6	0	2
(5) 1910	*Hip.* ♂ / *Tox.* ♀	4	6	49	1	45	5	0	1

Further data :

1909. Eggs fertilized in 400 c.c. sea-water + 20 drops $\frac{n}{10}$ acetic acid.
(1) 1910. Eggs fertilized in 500 c.c. sea-water + 15 drops $\frac{n}{10}$ acetic acid. 3 days.
(2) 1910. Eggs fertilized in 500 c.c. sea-water + 15 drops $\frac{n}{10}$ acetic acid. 4 days.
(3) 1910. Eggs fertilized in 500 c.c. sea-water + 15 drops $\frac{n}{10}$ acetic acid. 5 days.
(4) 1910. Eggs fertilized in 500 c.c. sea-water + 2 c.c. $\frac{n}{10}$ acetic acid. 2 days.
(5) 1910. Eggs fertilized in 500 c.c. sea-water + 2 c.c. $\frac{n}{10}$ acetic acid. 2 days.

The table shows clearly that the effect of the addition of the acetic acid had been to swing the dominance toward *Toxopneustes* side. That this result is not due to the specific action of the acetic acid is indicated by the results of fertilization in sea-water whose alkalinity has been decreased by the addition of hydrochloric acid.

TABLE V.—*Summary of results of cross-fertilization in sea-water of decreased alkalinity.*

[Hydrochloric acid. Number of plutei studied in each fertilization, 50. Temperature, 29°–29.5° C.]

Year.	Cross.	Plutei with lattice structure.	Anal arm rods with lattice structure.	Arms more than one rod.	Perfect *Hipponoë* rods.	Perfect *Toxopneustes* rods.	Perfect *Toxopneustes* plutei.	Perfect *Hipponoë* plutei.	Basket.
1909	*Hip.* ♂ *Tox.* ♀	5	8	52	4	40	10	0	–
(1) 1910	*Hip.* ♂ *Tox.* ♀	20	24	71	0	5	0	0	9
(2) 1910	*Hip.* ♂ *Tox.* ♀	17	17	79	0	4	0	0	13
(3) 1910	*Hip.* ♂ *Tox.* ♀	13	16	66	0	18	3	0	8
(4) 1910	*Hip.* ♂ *Tox.* ♀	6	9	51	0	40	4	0	2
(5) 1910	*Hip.* ♂ *Tox.* ♀	5	7	49	0	44	2	0	1

Further data:

1909. Eggs fertilized in 400 c.c. sea-water + 10 drops $\frac{n}{10}$ HCl.
(1) 1910. Eggs fertilized in 500 c.c. sea-water + 15 drops $\frac{n}{10}$ HCl. 3 days.
(2) 1910. Eggs fertilized in 500 c.c. sea-water + 15 drops $\frac{n}{10}$ HCl. 4 days.
(3) 1910. Eggs fertilized in 500 c.c. sea-water + 15 drops $\frac{n}{10}$ HCl. 5 days.
(4) 1910. Eggs fertilized in 500 c.c. sea-water+30 drops $\frac{n}{10}$ HCl. 2 days.
(5) 1910. Eggs fertilized in 500 c.c. sea-water+30 drops $\frac{n}{10}$ HCl. 2 days.

Table VI shows that the effect of the addition of the acid has been to swing the dominance in the *Hipponoë* ♀ × *Toxopneustes* ♂ cross to the *Toxopneustes* side:

TABLE VI.—*Summary of results of cross-fertilization in sea-water of decreased alkalinity.*

[20 drops $\frac{n}{10}$ acetic acid to 400 c.c. sea-water. Number of plutei studied, 50. Temperature, 29° C.]

Year.	Cross.	Plutei with lattice structure.	Anal arm rods with lattice structure.	Arms more than one rod.	Perfect *Hipponoë* rods.	Perfect *Toxopneustes* rods.	Perfect *Toxopneustes* plutei.	Perfect *Hipponoë* plutei.
1909	*Tox.* ♂ *Hip.* ♀	12	23	68	4	9	3	1

To facilitate comparison I combine all the statistics together in Table VII.

TABLE VII.—*Comparison of results of cross-fertilization.*

Year.	Cross.	Medium.	Plutei with lattice structure.	Anal arm rods with lattice structure.	Arms more than one rod.	Perfect *Hipponoë* rods.	Perfect *Toxopneustes* rods.	Perfect *Toxopneustes* plutei.	Perfect *Hipponoë* plutei.	Basket.
1909	*Hip.* ♂ / *Tox.* ♀	sea-water	33	60	39	14	1	0	5	
1909	*Tox.* ♂ / *Hip.* ♀	sea-water	37	58	40	30	2	0	12	
1909	*Hip.* ♂ / *Tox.* ♀	sea-water+ NaOH	39	57	40	15	2	0	3	
1909	*Tox.* ♂ / *Hip.* ♀	sea-water+ NaOH	40	62	38	31	0	0	10	
1909	*Hip.* ♂ / *Tox.* ♀	sea-water+ acetic	7	7	62	1	31	7	0	
(1) 1910	*Hip.* ♂ / *Tox.* ♀	sea-water+ acetic	4	5	93	0	2	0	0	7
(2) 1910	*Hip.* ♂ / *Tox.* ♀	sea-water+ acetic	14	16	81	0	3	0	0	10
(3) 1910	*Hip.* ♂ / *Tox.* ♀	sea-water+ acetic	13	15	69	0	16	3	0	12
(4) 1910	*Hip.* ♂ / *Tox.* ♀	sea-water+ acetic	3	5	51	0	44	6	0	2
(5) 1910	*Hip.* ♂ / *Tox.* ♀	sea-water+ acetic	4	6	49	1	45	5	0	1
1909	*Hip.* ♂ / *Tox.* ♀	sea-water+ HCl	5	8	52	4	40	10	0	–
(1) 1910	*Hip.* ♂ / *Tox.* ♀	sea-water+ HCl	20	24	71	0	5	0	0	9
(2) 1910	*Hip.* ♂ / *Tox.* ♀	sea-water+ HCl	17	17	79	0	4	0	0	13
(3) 1910	*Hip.* ♂ / *Tox.* ♀	sea-water+ HCl	13	16	66	0	18	3	0	8
(4) 1910	*Hip.* ♂ / *Tox.* ♀	sea-water+ HCl	6	9	51	0	40	4	0	2
(5) 1910	*Hip.* ♂ / *Tox.* ♀	sea-water+ HCl	5	7	49	0	44	2	0	1
1909	*Tox.* ♂ / *Hip.* ♀	sea-water+ acetic	12	23	68	4	9	3	1	

The first results of 1910 did not tend to confirm those of 1909. As I have already stated, another indication of *Hipponoë* dominance made its appearance, this being the basket. This character seemed especially difficult to control. The use of a greater amount of acid brought the results of the previous summer. One interesting thing in the work of 1910 was that the *Toxopneustes* ♀ × *Hipponoë* ♂ hybrids lived better in sea-water of reduced alkalinity than in the normal sea-water.

SUMMARY OF THE CONTROL OF DOMINANCE.

The outcome of the investigation may be summed up in the form of equations.

I. Ordinary Sea-Water.

$$\frac{\textit{Hippono\"{e}}\ ♂}{\textit{Toxopneustes}\ ♀} = \text{Dominant } \textit{Hippono\"{e}}.$$

$$\frac{\textit{Toxopneustes}\ ♂}{\textit{Hippono\"{e}}\ ♀} = \text{Dominant } \textit{Hippono\"{e}}.$$

II. Sea-Water + NaOH.

$$\frac{\textit{Hippono\"{e}}\ ♂}{\textit{Toxopneustes}\ ♀} = \text{Dominant } \textit{Hippono\"{e}}.$$

$$\frac{\textit{Toxopneustes}\ ♂}{\textit{Hippono\"{e}}\ ♀} = \text{Dominant } \textit{Hippono\"{e}}.$$

III. Sea-Water + Acetic or Hydrochloric Acid.

$$\frac{\textit{Hippono\"{e}}\ ♂}{\textit{Toxopneustes}\ ♀} = \text{Dominant } \textit{Toxopneustes}.$$

$$\frac{\textit{Toxopneustes}\ ♂}{\textit{Hippono\"{e}}\ ♀} = \text{Dominant } \textit{Toxopneustes}.$$

DISCUSSION OF RESULTS.

The task of bringing together and of harmonizing the results of various investigators is extremely difficult. Their results are diverse. In many cases the same forms worked with in the same localities, at the same time of year, but in different years, have given at one time one result, at another time another result. Yet the work has been done by investigators whose ability is unquestionable.

I may be criticized for having given so full a résumé of the papers of Herbst and of Vernon. I have done this for the purpose of giving an exact account of our present knowledge of Echinoderm hybridization, which I hope may be useful.

I have already stated that I regard the material with which I have worked as especially fortunate, more fortunate than that which has been obtained by any other investigator. This is for two reasons,

(1) Reciprocal crosses were readily made and the plutei from both were well formed.

(2) A clear preponderance of *Hipponoë* characters was evident, no matter which way the cross was made.

In the résumé of the literature of the subject that I have given and in my own work one thing stands out clearly: This is the "optimum."

Herbst determined an optimum concentration of OH ions in the sea-water of the Gulf of Naples; an optimum OH ion concentration in his cross-fertilization researches; an optimum temperature for development. Vernon determined optimum temperature, light, season, concentration of sea-water, etc. My own studies have shown an optimum time for fertilization, an optimum concentration of OH ions, etc.

Everything points to an optimum environment and a necessary environment for certain occurrences. This is only what we expect. One aim of scientific research is to determine the conditions in which certain phenomena will be exhibited. Our evidence has shown the delicacy of the balance between an exhibition of *Hipponoë* characters and the appearance of *Toxopneustes* characters. We are not surprised that this should be so, now that we have seen it. It is what we might expect in forms which are so closely similar.

In comparing the change of dominance which I obtained by change in alkalinity of the sea-water with that which Herbst obtained by changing temperature, it is interesting to notice that the normal temperature of the sea-water in the tropical and subtropical regions in which my work has been done is higher than those of Herbst's experimental conditions.

In this comparison (see tables on pages 128 and 147) it will be seen that the changes caused by increased temperature and the changes caused by decreased alkalinity are approximately the same. I have reduced the amount of *Hipponoë* dominance in about the same amount that Herbst has decreased the amount of *Strongylocentrotus* influence. In the cross *Sphærechinus* ♀ × *Strongylocentrotus* ♂, Herbst has held the embryo to the egg type.

The difference between Herbst's observations and my own is more apparent than real. By one change in environment I have obtained embryos of a *Hipponoë* type; by another change of environment, I have obtained embryos of the *Toxopneustes* type. Herbst by combining artificial parthenogenesis and fertilization held the embryo to the egg type.

As to the explanation of this phenomenon, I believe that we have it in the optimum which was produced by the change in environment. In work with the pure forms Herbst, Vernon, and I have shown that uniformly the best results are obtained in certain definite conditions. I have shown that a higher degree of alkalinity is more favorable to *Hipponoë*, a lesser degree to *Toxopneustes*. If the fertilization be made in the environment most favorable to the sperm, and therefore possibly most favorable to the growth of its nuclear material, resemblance to the male parent has followed in both cases.

That the results are not uniform depends upon individual differences in the germ-cells, although in general the germ-cells in a given parent produce embryos of a similar character. This idea of individual differences is simply the idea of chemical variation in the germ-cells which has arisen during their growth, a variation due to food, functional reactions, etc.

I have done nothing which will explain the "cause" of these phenomena. I have simply shown that, in the material with which I worked, definite phenomena are exhibited in certain conditions. I believe that Herbst (1907) and I worked with essentially the same factors, although we applied them in a somewhat different manner—in his case the method of treatment being sufficient to cause parthenogenesis, in my work the method of application not being sufficient.

We have by no means exhausted all of the influential factors. Herbst found a partial control in temperature. From my investigations I believe that another partial control lies in the concentration of OH ions in the sea-water in which development is taking place. Given an optimum concentration, we may expect certain occurrences.

The "unknown factor" is a complex of conditions made up of factors, each one of which represents the optimum environment, an environment in which the same thing may always be expected to occur. It is by a change from the optimum of one form to that of another that we may expect to bring about change in structure.

I stated in the beginning that the aim of this investigation is a formulation of a statement of the conditions governing the resemblance of the offspring to the parent. That aim has been at least partially accomplished by the research.

We have definite evidence that temperature and OH ion concentration of the sea-water are factors whose variation determines in part this resemblance to one or the other parent. In other words, the structure of the sea-urchin pluteus from cross-fertilized eggs may be influenced by the external environment to which the developing germ is subjected during its growth.

In a preliminary paper (1910*a*) I criticized Herbst's idea of nuclear control. Our evidence, I believe, all points to a physical-chemical control. This control is exerted on the germ-cell from its beginning. This control is the complex of factors forming the environment of the germ-cell during its growth in the body of the parent and (in forms in which fertilization and development take place outside of the body) the environment in which growth takes place. For the agent through which this control is exerted, much evidence shows that we may look to the nucleus.

A further generalization from my observations would be premature. We do not know how permanent the changes in structure may be. That knowledge can be gained only by a study of later generations raised from cross-fertilized eggs.

SUMMARY.

(1) The *Toxopneustes* ♀ × *Hipponoë* ♂ and the reciprocal cross *Hipponoë* ♀ × *Toxopneustes* ♂ were easily made after allowing the eggs to stand in sea-water for some hours before fertilization.

(2) In the embryos of both crosses made in ordinary sea-water, which was alkaline, the *Hipponoë* influence showed a tendency to predominate.

(3) In the embryos of both crosses made in sea-water of increased alkalinity, there was evidence of an increase of *Hipponoë* influence.

(4) In the embryos of both crosses made in sea-water of decreased alkalinity, a tendency toward *Toxopneustes* dominance was evident.

(5) The results thus show *Hipponoë* dominance in sea-water of a higher OH ion concentration and *Toxopneustes* dominance in sea-water of a lower OH ion concentration.

(6) I suggest that these variations in the alkalinity of the sea-water, which I have brought about artificially, may correspond to normal seasonal changes.

(7) If this be true, the winter (paternal) embryos and the summer (maternal) plutei of the combination *Sphærechinus* × *Strongylocentrotus* of other investigators had their origin in such normal seasonal changes of OH ion concentration.

(8) The results of this and of other investigations show species tendencies toward different grades of temperature and of alkalinity.

(9) The explanation of the preponderance of one character over another in Echinoderm hybrids seems to lie in the reaction of the species toward a complex of factors.

MODESTO, CALIFORNIA, *July*, 1910.

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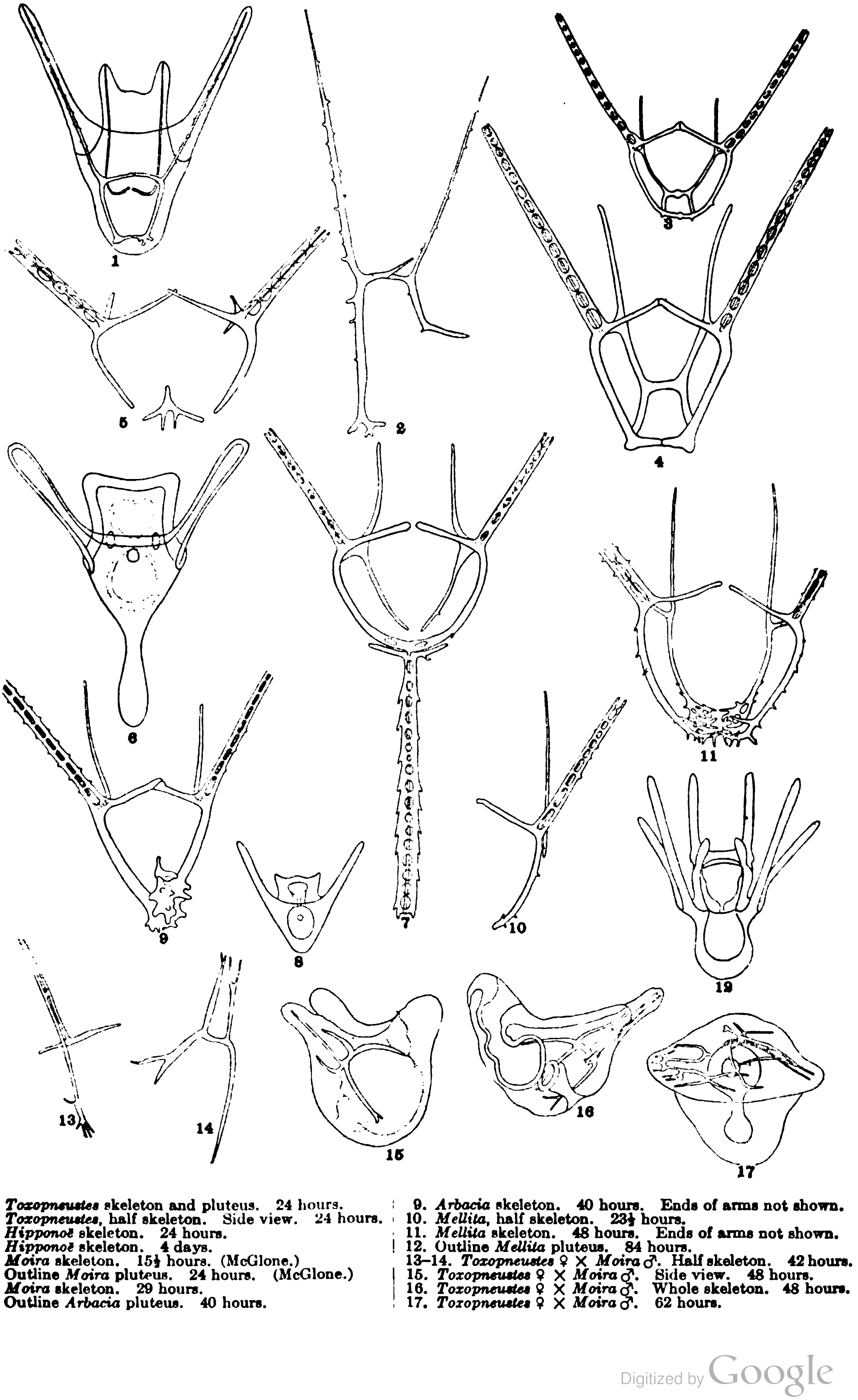
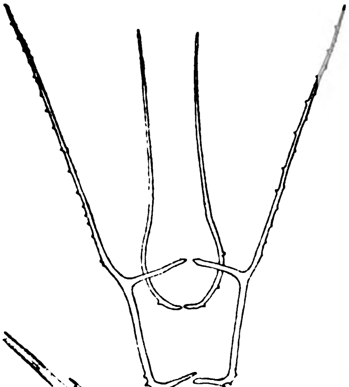


1. *Toxopneustes* skeleton and pluteus. 24 hours.
2. *Toxopneustes*, half skeleton. Side view. 24 hours.
3. *Hipponoë* skeleton. 24 hours.
4. *Hipponoë* skeleton. 4 days.
5. *Moira* skeleton. 15½ hours. (McGlone.)
6. Outline *Moira* pluteus. 24 hours. (McGlone.)
7. *Moira* skeleton. 29 hours.
8. Outline *Arbacia* pluteus. 40 hours.
9. *Arbacia* skeleton. 40 hours. Ends of arms not shown.
10. *Mellita*, half skeleton. 23½ hours.
11. *Mellita* skeleton. 48 hours. Ends of arms not shown.
12. Outline *Mellita* pluteus. 84 hours.

13–14. *Toxopneustes* ♀ × *Moira* ♂. Half skeleton. 42 hours.

15. *Toxopneustes* ♀ × *Moira* ♂. Side view. 48 hours.
16. *Toxopneustes* ♀ × *Moira* ♂. Whole skeleton. 48 hours.
17. *Toxopneustes* ♀ × *Moira* ♂. 62 hours.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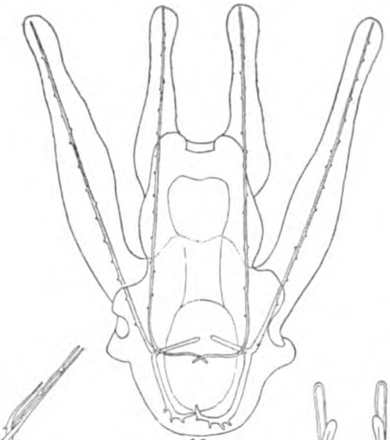
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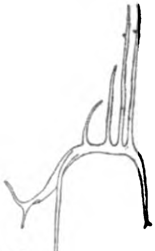
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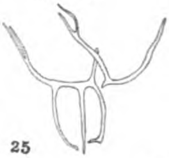
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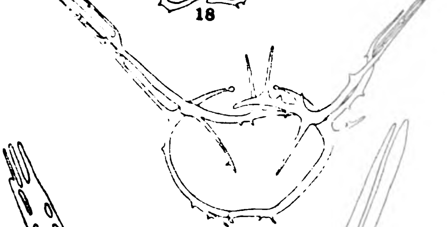
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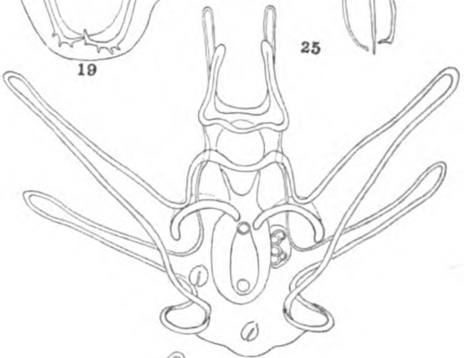
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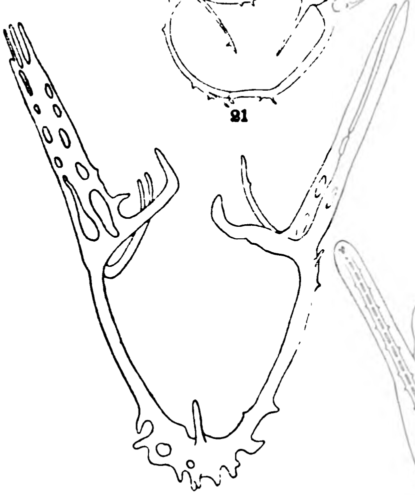
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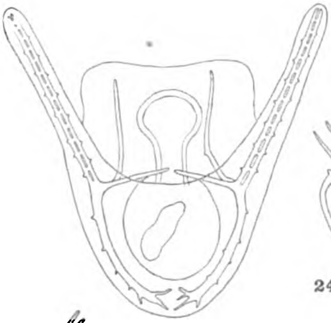
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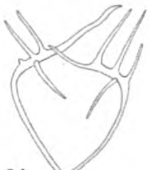
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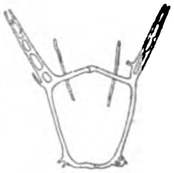
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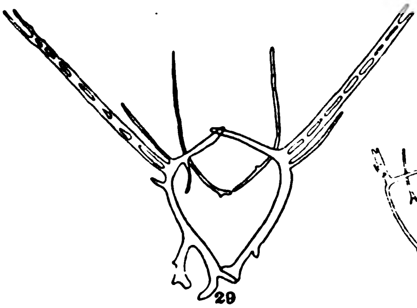
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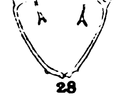
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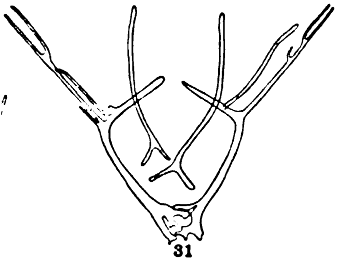
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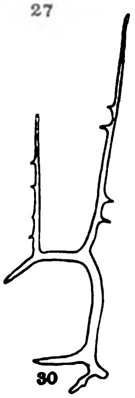
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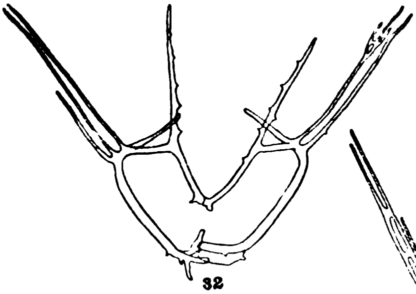
18. *Toxopneustes* ♀ × *Moira* ♂. Half-skeleton. 60 hours.
19. *Toxopneustes* ♀ × *Moira* ♂. Pluteus and skeleton. 6 days.
20. *Toxopneustes* ♀ × *Moira* ♂. Pluteus. Free hand. 15 days.
21. *Toxopneustes* ♀ × *Mellita* ♂. Skeleton. 48 hours.
22. *Arbacia* ♀ × *Mellita* ♂. 48 hours.
23. *Mellita* ♀ × *Moira* ♂. 36 hours.
24. *Moira* ♀ × *Toxopneustes* ♂. 36 hours.
25–26. *Moira* ♀ × *Toxopneustes* ♂. 36 hours.
27. *Toxopneustes* ♀ × *Hipponoë* ♂. 48 hours.
28. *Hipponoë* ♀ × *Toxopneustes* ♂. 48 hours.
29–31. *Toxopneustes* ♀ × *Hipponoë* ♂. NaOH. Fourth day.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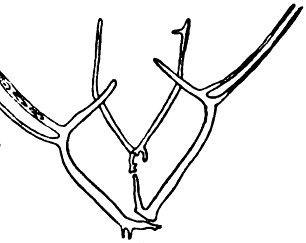
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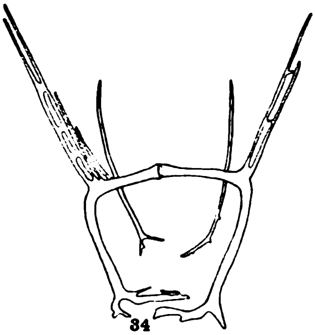
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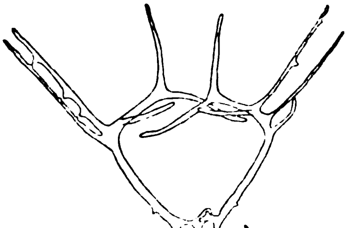
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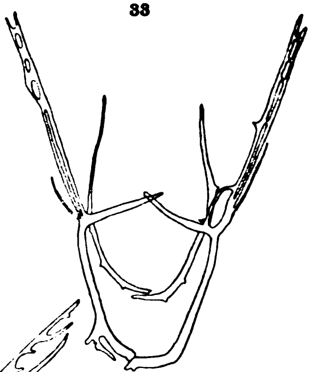
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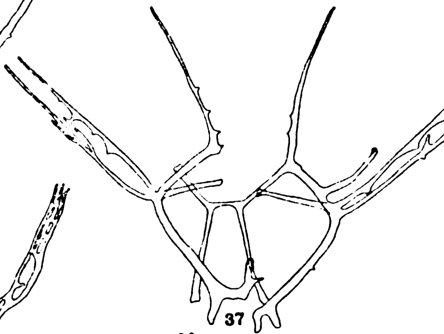
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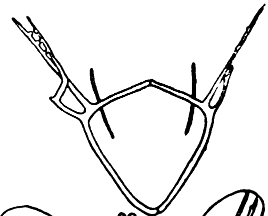
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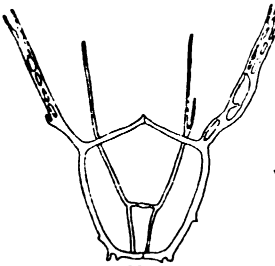
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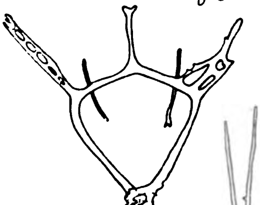
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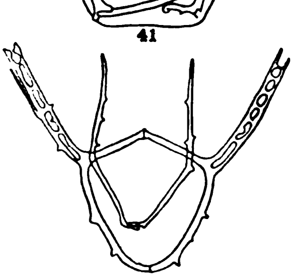
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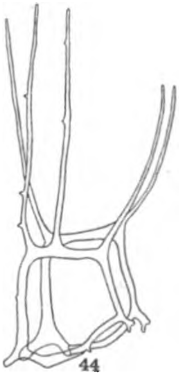
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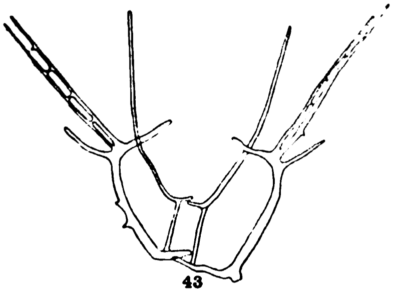
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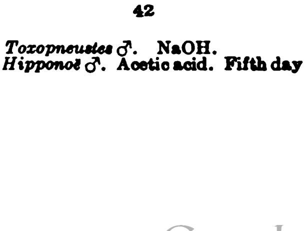
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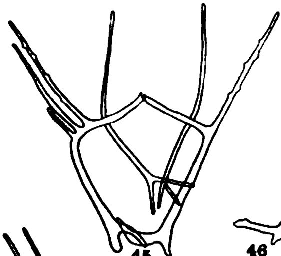
32–37. *Toxopneustes* ♀ × *Hipponoë* ♂. NaOH. Fourth day.
38–41. *Hipponoë* ♀ × *Toxopneustes* ♂. NaOH. Fourth day.

42–43. *Hipponoë* ♀ × *Toxopneustes* ♂. NaOH.
44. *Toxopneustes* ♀ × *Hipponoë* ♂. Acetic acid. Fifth day.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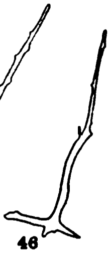
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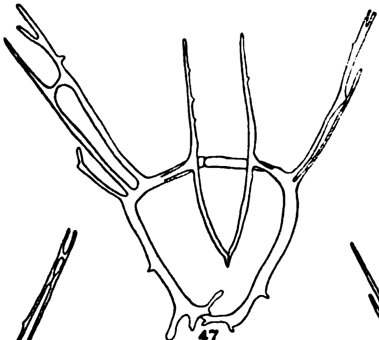
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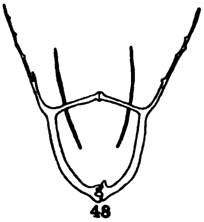
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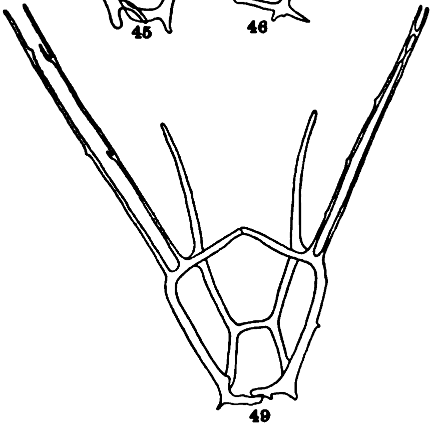
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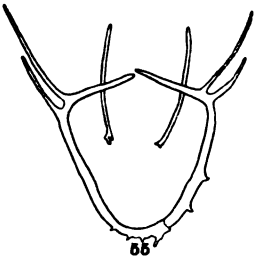
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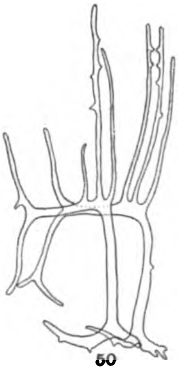
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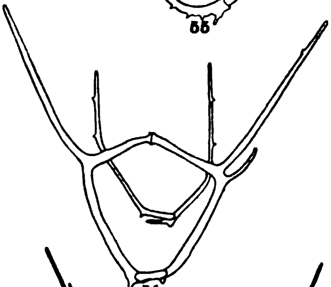
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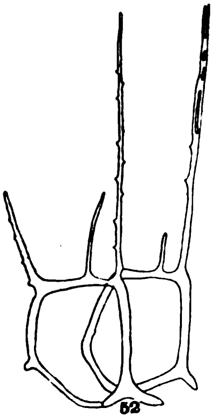
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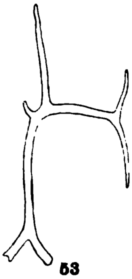
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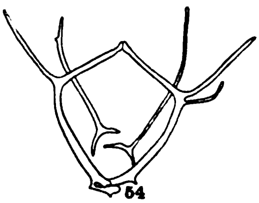
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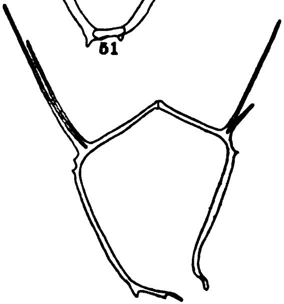
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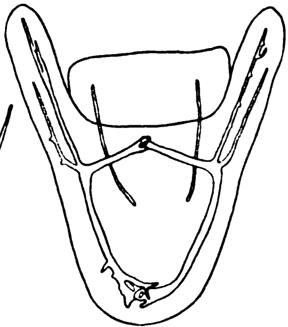
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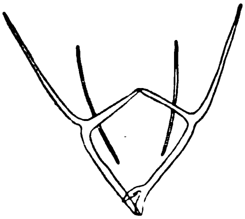
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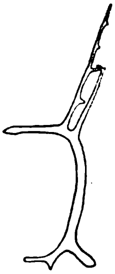
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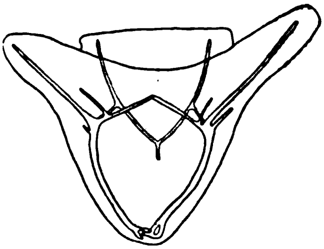
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45–46. *Toxopneustes* ♀ × *Hipponoë* ♂. Acetic acid. Third day.

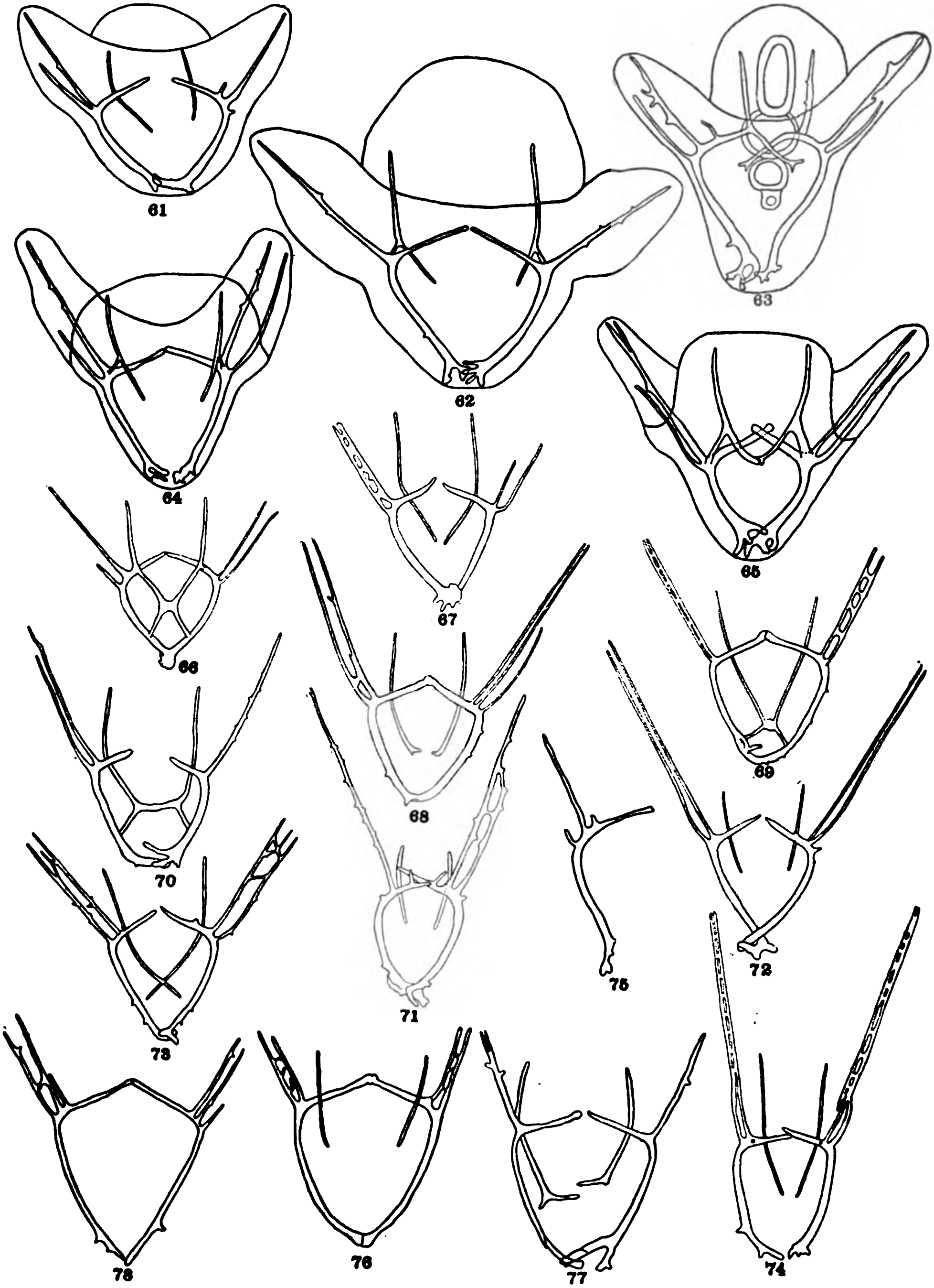
47. *Toxopneustes* ♀ × *Hipponoë* ♂. Acetic acid. Fifth day.

48. *Toxopneustes* ♀ × *Hipponoë* ♂. Acetic acid. Third day.

49–53. *Toxopneustes* ♀ × *Hipponoë* ♂. Acetic acid. Fifth day.

54–56. *Toxopneustes* ♀ × *Hipponoë* ♂. Acetic acid. Third day.

57–60. *Toxopneustes* ♀ × *Hipponoë* ♂. Acetic acid.



61–65. *Toxopneustes* ♀ × *Hipponoë* ♂. Acetic acid.

66–69. *Toxopneustes* ♀ × *Hipponoë* ♂. 1910. Ordinary sea water. 3 days.

70–72. *Toxopneustes* ♀ × *Hipponoë* ♂. HCl. 4 days.

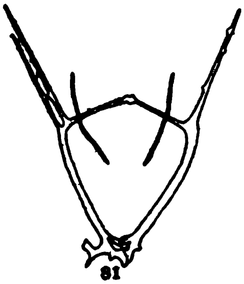
73. *Toxopneustes* ♀ × *Hipponoë* ♂. 1910. Acetic acid. 4 days.

74. *Toxopneustes* ♀ × *Hipponoë* ♂. 1910. Acetic acid. 5 days.

75–76. *Toxopneustes* ♀ × *Hipponoë* ♂. Normal sea water.

77. *Toxopneustes* ♀ × *Hipponoë* ♂. Acetic acid.

78. *Toxopneustes* ♀ × *Hipponoë* ♂. HCl.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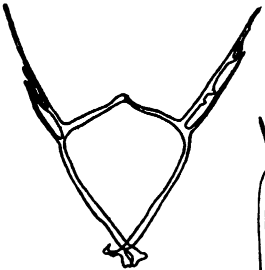
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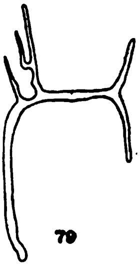
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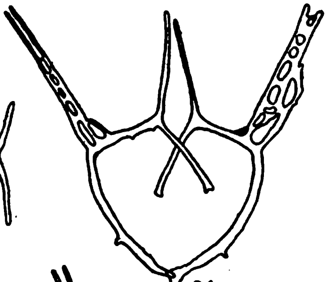
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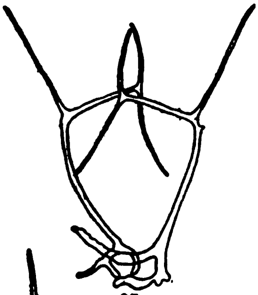
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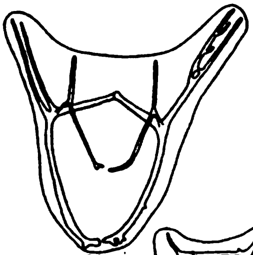
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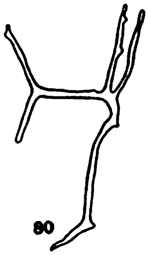
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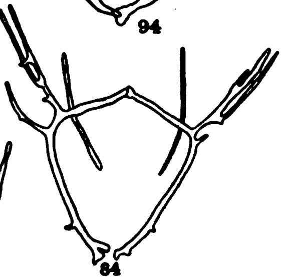
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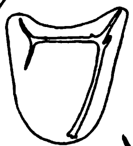
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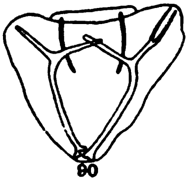
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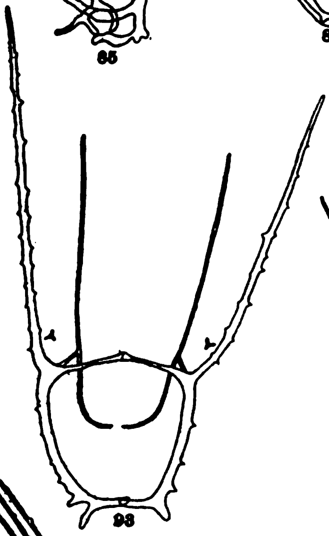
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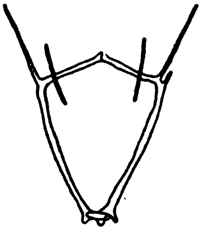
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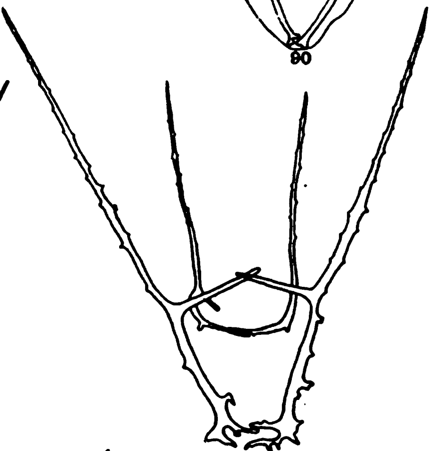
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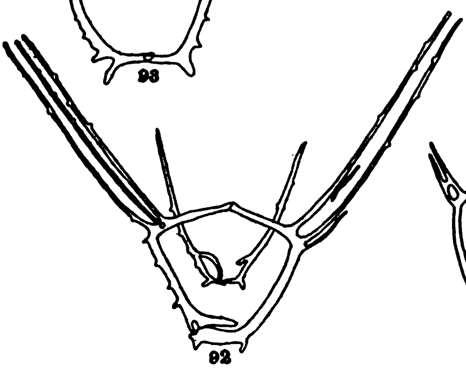
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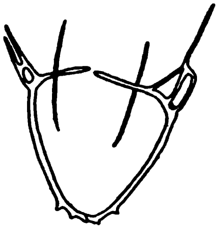
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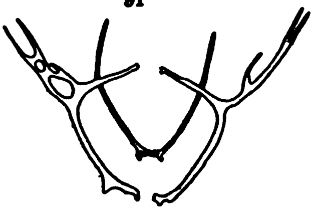
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79. *Toxopneustes* ♀ × *Hipponoë* ♂. 1910 Acetic acid.
80–85. *Toxopneustes* ♀ × *Hipponoë* ♂. 1910. HCl.
86. *Hipponoë* ♀ × *Toxopneustes* ♂. NaOH.

87–90. *Hipponoë* ♀ × *Toxopneustes* ♂. Acetic acid.
91–93. *Hipponoë* ♀ × *Toxopneustes* ♂. Acetic acid.
94. *Toxopneustes* ♀ × *Hipponoë* ♂. NaOH.

DEPARTMENT OF MARINE BIOLOGY
OF
CARNEGIE INSTITUTION OF WASHINGTON
ALFRED G. MAYER, DIRECTOR

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By HENRY S. PRATT.

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By EDWIN LINTON.

A CONTRIBUTION TO THE GEOLOGIC HISTORY OF THE FLORIDIAN PLATEAU.

By THOMAS WAYLAND VAUGHAN.

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A NEW MONOGENETIC TREMATODE.

By HENRY S. PRATT,
Haverford College.

11 figures.

MONOCOTYLE FLORIDANA, A NEW MONOGENETIC TREMATODE.

By Henry S. Pratt.

The genus *Monocotyle* was established by Taschenberg, in 1878, for a worm which he had found on the gills of the eagle-ray (*Myliobatis aquila*) at Naples, and which he named *Monocotyle myliobatis*. The only other known species is *Monocotyle ijimæ*, which was discovered in Japan in the mouth of *Trygon pastinacea*, and described by Goto in 1894. The worm herein described makes the third member of the genus and was taken from the gills of the whip-ray (*Myliobatis freminvillei*) in the Gulf of Mexico and studied at the Marine Biological Laboratory of the Carnegie Institution of Washington at Tortugas, Florida. It differs in certain features from the two other species of the genus, but in the general shape and size of the body, the form and structure of the suckers, down to the smallest details, and the general arrangement of the genital organs it shows a close relationship to them, especially to *M. ijimæ*. *M. aquila* is not well known anatomically. Its male genital organs have not been seen at all and the descriptions of the female genital tract are not complete.

The body of *Monocotyle floridana* is elongate and thin, being convex dorsally and flattened ventrally. A large individual, selected for description, measures 1.3 mm. in length and 0.58 mm. in width in the widest place, which is just back of the middle, and is about half as long as the Japanese and a third as long as the Mediterranean species. From the widest point the body tapers towards both ends. The anterior end is usually more or less truncated, as in *M. ijimæ*, and also possesses the sticky glands which characterize that species. These glands (fig. 2) are four in number and are dorsal in position, lying embedded in the muscle of the oral sucker; but instead of being near the surface or at the forward end of the body, they are situated at a considerable distance from the forward end, as is also the case in the closely allied genus *Calicotyle*, being dorsal to the brain, and are joined with the forward end of the body by long sinuous ducts. Each gland is irregular in shape and about 0.03 mm. long, while its duct has a length of about 0.17 mm.

The mouth is a large funnel-shaped opening, subterminal in position, 0.10 mm. in diameter and 0.12 mm. deep. It is surrounded by a lip-like projection which forms a slight flange posteriorly and laterally and which extends forward anteriorly and dorsally beyond the end of the body (figs. 1, 2, and 3, *l.*). This lip is non-muscular and apparently receives the secretions of the four glands just mentioned. Surrounding the mouth is a powerful sucker which entirely fills the anterior end of the body, but is not separated from the parenchyma by a definite boundary. Goto describes a similar structure in *M. ijimæ* as a sucker-like organ which, as he says, undoubtedly functions as a sucker. He refuses, however, to recognize it morphologically as a sucker because of the lack of definite boundaries.

The posterior sucking-disk is not so large relatively as in the other two species of the genus, having a diameter of 0.52 mm., which is somewhat less than that of the body (figs. 1 and 4). It is circular in outline and shaped more or less like a saucer, having a curled rim, and is subterminal in position, being attached to the body by a short, thick peduncle. The ventral surface of the disk is divided by eight radial ridges into as many segments, each of which contains a large oval sucker about c.1 mm. in diameter. The sucker occupies about two-thirds of the space in the segment, extending from the outer rim or margin of the disk to the peduncle. The center of the disk, where the peduncle is attached, is somewhat depressed (fig. 5, *c.d.*) and contains no muscular tissue. The parenchyma, however, immediately beneath the cuticula in the center is arranged in parallel lines perpendicular to the cuticula and has somewhat the appearance of a musculature. Extending from the outer margin of the sucking-disk is a lip or flange of non-muscular tissue (figs. 5 and 6, *fl.*) similar to the lip at the anterior end of the body. It will be seen that the sucking-disk is not a single sucker, as it is described as being in the other two species of the genus, but a pedunculated plate containing eight distinct suckers.

Two small hooks (fig. 1, *h.*, fig. 7) are embedded in two of the posterior radii of the sucking-disk, but do not usually extend beyond the margin. Each hook has two parts, a crescentic portion 0.027 mm. in diameter and a straight portion extending from it, 0.034 mm. long.

On the dorsal or reverse side of the sucking disk, opposite to the two posterior segments and between the two hooks, are two groups of short finger-like projections (figs. 4 and 5, *d.p.*). Each group is V-shaped, with the apex directed towards the center of the disk, and each projection has the same structure as the suckers. No similar structures, so far as I know, have been observed in any other trematode.

Goto has called attention to the unusual structure of the musculature of the sucking-disk in *M. ijimæ*, the radial muscle-fibers composing the main mass of the disk being striated. In *M. floridana* identical relations exist. The musculature of the suckers of the disk is made up principally of perpendicular striated fibers (fig. 6, *s. m.*), most of which run independently from the cuticula on one side of the sucker to that on the other. Between the ends of these fibers are very delicate non-striated fibers which run parallel to the cuticula. The muscle-fibers composing the dorsal finger-like projections have a direction transverse to that of those of the suckers (fig. 5, *d.p.*).

The body of the worm is smooth. The chitinous pieces on the radial elevations of the sucking-disk which have been described by Goto in *M. ijimæ* are not present.

The large mouth opens through a small passage into the pharynx, receiving at the juncture a circular pocket which lies over the anterior end of the pharynx (fig. 3, *p.p.*). The pharynx is of enormous size, being 0.19 mm. long, 0.18 mm. wide, and 0.17 mm. thick in the worm selected for description, and is the most conspicuous organ in the body (figs. 1 and 3, *ph.*); but it varies considerably in relative size in different individuals, being relatively smallest in the youngest individuals. In the smallest worms in my collection its length is one-twelfth that of the body; in the largest this proportion is 1 to 6. The small lumen is three-cornered in cross-section and the walls are very thick and composed of closely compacted, deeply staining radial muscle-fibers. Sparsely distributed throughout these fibers are large oval cells, which are probably nerve-ganglia. Surrounding the radial fibers is a thin layer of delicate circular fibers.

The intestine branches just back of the pharynx, there being no esophagus present (figs. 1 and 3). The two intestinal trunks pass directly to the right and left sides of the body. They then pass first forward a short distance, and then, turning abruptly, run posteriorly along the medial surfaces of the voluminous yolk-glands and parallel to the lateral margins of the body to the hinder part of it, where their posterior ends meet and unite (figs. 1 and 4). In the two other species of this genus the hinder ends of the intestinal trunks do not thus join, but remain apart.

The diameter of each trunk is about 0.04 mm. in a large individual. Projecting posteriorly from the point of juncture of the two lateral trunks in all the individuals examined by me (about twenty-five), is a median trunk which extends to the extreme hinder end of the body (figs. 1 and 4 *m. t.*). This median trunk has exactly the same structure as the lateral trunks and about the same diameter (figs. 9, 10, 11); but in several individuals it was much thicker than they and took stains much more deeply.

In two individuals examined the median trunk opens to the outside by means of a median, dorsal, thick-lipped pore, situated at the extreme posterior end of the body and just in front of the point of attachment of the sucking-disk (fig. 4, *t. p.*). In all other individuals examined no such pore could be seen and the median trunk ends blind, forming thus a cæcum.

The occurrence of a median, posterior intestinal cæcum similar to the one here described is exceedingly rare among trematodes, the only other species with which I am acquainted in which it occurs being *Vallisia striata*, which has been described by Perugia and Parona (1890). The terminal pore is difficult to explain and may be simply an accidental opening in the two individuals in which it was seen, although its well-defined form and broad lips would seem to preclude this interpretation.

The excretory system has not been distinctly seen, but has undoubtedly the same arrangement as that described by Goto in *M. ijimæ* and in other monogenetic trematodes. The longitudinal trunks are small and delicate tubes which open to the outside through a pair of lateral pores situated at about the level of the hinder part of the pharynx, each pore being in the dorsal surface a short distance from the lateral margin of the body.

The nervous system is also of the usual type, the brain lying dorsal to and just in front of the pharynx (fig. 1, *b.*) and the anterior and posterior paired nerves extending from its lateral ends to the extremities of the body (fig. 1, *a. n.*, *l. n.*). The main posterior nerves run lateral to the massive yolk-glands and along the margin of the body. No ocelli are present.

The genital organs are similar in arrangement to those of *M. ijimæ.* The single testis (figs. 1 and 8, *t.*) is a spherical structure 0.115 mm. in diameter, which lies just back of the middle of the body at the left of the median line. In *M. ijimæ* three testes are present, while in *M. myliobatis* no one has yet seen any of the male genital organs. The vas deferens (figs. 1 and 8, *v. d.*) is a narrow tube with rather thick, structureless, highly refractive walls; it arises from the anterior surface of the testis and passes forward at the left of the median line to the vaginal pore (figs. 1 and 8, *v. p.*), which is situated in the ventral surface on the left side of the body near the hinder end of the pharynx. No penis, cirrus, or vesicula seminalis is present, the vas deferens having exactly the same structure and diameter from one end of it to the other. I have also been unable to detect any trace of specialization in the parenchyma surrounding the anterior end of the vas deferens, such as is present in *M. ijimæ* and forms the so-called connective-tissue penis in that species.

The ovary (figs. 1 and 8, *o*) is made up of two distinct portions, one of which, the formative portion, is spherical in shape and about the same size as the testis, and lies immediately in front and at the side of it at the right of the median line. The other portion is cylindrical in shape and extends from the spherical portion to the right side of the body, where it forms a single loop around the right intestinal trunk, tapering in size as it proceeds until it becomes so narrow that it contains but a single row of elongated ova. It thus runs to the left side of the body, where it passes, without further decrease in size, into the oviduct, which is a very short tube (fig. 8, *ov.*), which joins the posterior surface of the ootype. The ova filling the ovary are of large size, those in the cylindrical portion being about 0.025 mm. long and 0.013 mm. thick.

The ootype (figs. 1 and 8, *oot.*) is a large spherical sac, about 0.09 mm. in diameter and with thick walls, which is situated just in front of the ovary on the left side and near the dorsal surface of the body. The walls are composed of a high pavement-epithelium of deeply staining, glandular cells, which forms the interior surface of the organ, and a layer of rather delicate muscle-fibers lying back of it. Grouped at the antero-medial side of the ootype, where the uterus leaves it, are the large pear-shaped cells which form the shell-gland. The ootype occasionally contains a single large oval egg (fig. 8, *e.*), which about half fills it and has a length of about 0.045 mm. and a thickness of 0.03 mm. Projecting from the hinder end of the egg, as it lies in the ootype, is a short, straight chitinous process about 0.02 mm. long. It seems certain that the chitinous chorion of the egg is formed from the secretion of the epithelial lining of the ootype, as well as from that of the shell-gland.

Extending from the ootype to the birth-pore (figs. 1 and 8, *b. p.*) is the uterus (figs. 1 and 8, *u.*). This vessel is a long tube of large size at its point of origin at the ootype, which makes two complete turns, first running forwards, then backwards, and finally forwards again, passing ventral to the intestine and dorsal to the receptaculum seminis and opening to the outside at the birth-pore. Its diameter decreases towards its forward end, and throughout the greater part of its extent it is a very narrow tube. It possesses, however, a chitinous lining which renders it a conspicuous object under the microscope. The birth-pore is situated in the ventral surface of the body in the median line near the hinder end of the pharynx.

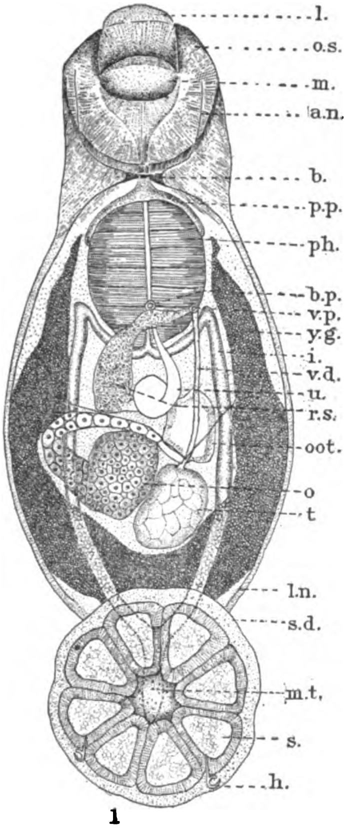
The vagina (fig. 8, *v.*) is very short and leads from the vaginal pore (fig. 8, *v. p.*) on the left side of the body near the hinder end of the pharynx across to the right side of the body and into the large cylindrical receptaculum seminis (figs. 1 and 8, *r. s.*). This is a prominent thin-walled organ, always filled with sperm, which lies just back of the pharynx on the right side and near the ventral surface of the body. Its hinder end is rounded and about 0.08 mm. in diameter, and is connected with the uterus by means of a short canal.

The yolk-glands consist of small, closely compacted spherical follicles and are very voluminous. They extend from the forward portion of the pharynx to the hinder end of the body, occupying the areas lateral to the intestinal trunks as far back as the hinder end of the ovary and testis. Posterior to these organs they fill the entire body, completely immersing the hinder portions of the digestive tract. The two transverse yolk-ducts lie in very nearly the middle of the body. They meet near the hinder end of the ootype and form a very short common duct, which enters the oviduct almost at the point where it enters the ootype. No yolk reservoir is present. No genito-intestinal canal is present.

The genital organs of this worm exhibit several interesting and unusual features. As will have been noticed, there is here no common genital pore. The vas deferens, instead of opening to the outside together with the uterus, finds an outlet, as I have determined with perfect certainty, through the vaginal pore, and the sperm undoubtedly passes directly from the vas deferens through the vagina and into the receptaculum seminis of the same animal. The self-fertilization which is thus brought about may be necessary because of the total lack of a penis and a vesicula seminis.

The receptaculum seminis, as in other monogenetic trematodes, is nothing more than a distended portion of the vagina and is invariably filled with sperm in all the worms I have studied. The vagina is peculiar in that it opens into the uterus near the forward end of the ootype instead of into the oviduct or the yolk-duct near the hinder part of that organ.

The birth-pore is what is left of the common genital pore after the migration of the terminal end of the vas deferens to the vaginal pore,



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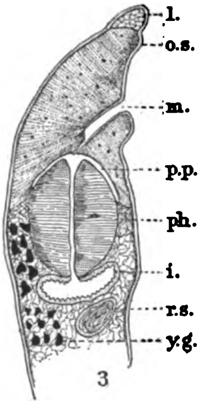

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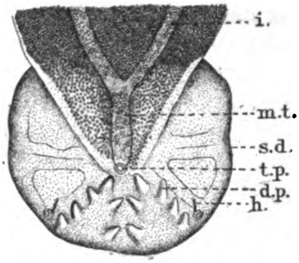

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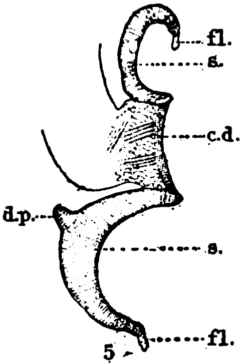

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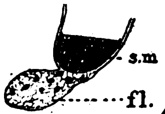

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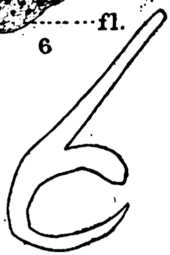

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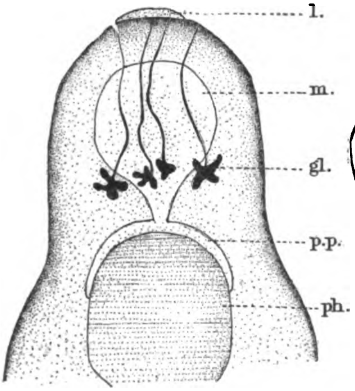

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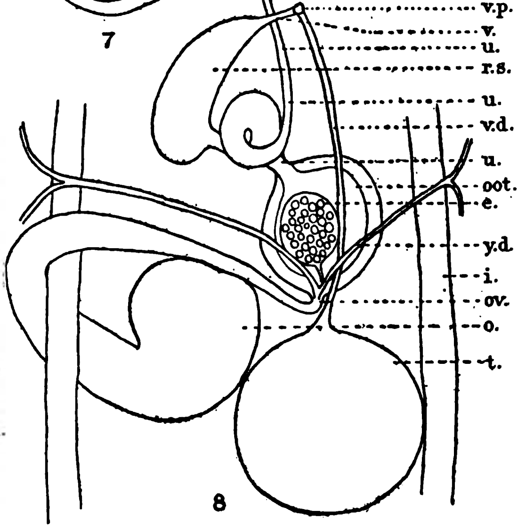

8

1. The whole worm viewed from ventral side: actual length 1.3 mm.
2. Dorsal surface of anterior portion of worm: × 25.
3. Sagittal section of anterior portion of worm: × 18.
4. Dorsal view of posterior portion of worm: × 20.
5. Longitudinal section of sucking-disk and peduncle: × 40.
6. Section of outer portion and flange of a sucker : × 200.
7. Hook in sucking-disk: × 150.
8. Diagram showing arrangement of reproductive organs.

and serves as the outlet of the uterus alone. It will at once be noticed that the birth-pore is a very small opening and the uterus is a very narrow tube and that the egg which must pass through them is several times their width. It is evident, consequently, that they must be capable of great distention while the egg is being extruded. In fact, although no individuals have come under my observation in which an egg is present in the uterus, I have seen several individuals in which the terminal portion of the uterus is very much distended and several times its usual width.

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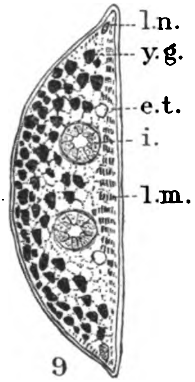

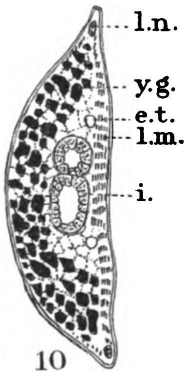

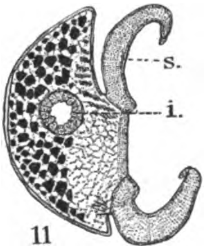

9. Transverse section of worm back of testis: × 25.
10. Transverse section of worm where the intestinal trunks meet: × 25.
11. Transverse section of worm showing median trunk of intestine: × 25.

Abbreviations used on Figures.

a. n.	anterior nerve.
b. p.	birth-pore.
b.	brain.
c. d.	center of sucking-disk.
d. p.	dorsal projection of sucker.
e.	egg.
e. t.	excretory trunk.
fl.	flange of disk.
gl.	glands.
h.	hooks.
i.	intestine.
l.	lip.
l. m.	longitudinal muscles.
l. n.	longitudinal nerve (posterior).
m.	mouth.
m. t.	median trunk of intestine.
o.	ovary.
oot	ootype.
o. s.	oral sucker.
ov	oviduct.
ph	pharynx.
p. p.	pharyngeal pocket.
r. s.	receptaculum seminis.
s.	sucker.
s. d.	sucking disk.
s. m.	striated muscles.
t.	testis.
t. p.	terminal pore.
u.	uterus.
v.	vagina.
v. p.	vaginal pore.
y. d.	yolk-duct.
y. g.	yolk-glands.

HELMINTH FAUNA OF THE DRY TORTUGAS.

II. TREMATODES.

By EDWIN LINTON,
Professor of Biology, Washington and Jefferson College.

28 plates.

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HELMINTH FAUNA OF THE DRY TORTUGAS.

II. TREMATODES.

By Edwin Linton.

INTRODUCTION.

The collection here described was made at the Marine Biological Laboratory of the Carnegie Institution, Tortugas, Florida, in the summers of 1906, 1907, and 1908. In each season my stay at the Laboratory was about three weeks. Without exception the fishes examined were from the shallow waters of the reef. Tables showing the distribution of parasites together with food notes have already been published in the Year Book of the Carnegie Institution of Washington for the years above named.

While the exact method of collecting material varied with the size and number of the hosts, in general I found it best to open the alimentary canal, wash out the contents with sea-water, wash and decant several times if necessary, and then collect the small distomes with a pipette. The distomes were killed in various ways, hot corrosive sublimate, picro-sulphuric acid, etc. A very satisfactory way for whole mounts is a method used by Fuhrmann, viz., kill in 70 per cent alcohol and stain in very dilute hæmatein. Preliminary to this it is a good plan to flatten the distome under a cover-glass and heat it a little before placing in the killing fluid. My best sections are from material fixed in picro-sulphuric acid, although material killed in hot corrosive sublimate and stained with carmine is usually very satisfactory. In spite of precautions much material which one collects proves unsatisfactory or difficult. In many of the smaller distomes the vitellaria conceal the general anatomy. In other cases the uterus is so full of eggs that other parts are obscured or displaced. Again, the spinose cuticle is often evanescent, and one is frequently much puzzled over a specimen that has a close resemblance to forms with spines, but which is itself entirely destitute of spines or of any certain indications that it ever had spines.

All measurements are given in millimeters.

Where no other habitat is mentioned the intestine is to be understood as the habitat.

I am disposed to think that modern helminthologists have unduly narrowed the idea of genus among the distomes. At the same time I recognize the futility of attempting any change at present in the conception of what should constitute a generic character in this difficult group. Therefore, since I find it quite impossible to secure an abiding-place for a majority of the Tortugas distomes in any existing genera, I have thought it best to make new genera rather than to extend the limits of genera that have been established. It has been my aim to describe such details of structure as I was able to make out from the living material and supplement it with further details obtained from stained and mounted specimens. In many cases I was able to get fairly satisfactory series of sections, in which case such details as seemed to me to be of service in identification, or which appeared to be new, were added. Since this paper contains mention of all the trematodes which I found while at the Tortugas laboratory, it is unavoidable that many of the descriptions will be incomplete in some particulars. If the paper were intended simply as a contribution to systematic zoölogy, only those forms would have been included which were represented by abundant material or by material in good condition for study. Since my purpose is to make a contribution to the knowledge of the helminth fauna of the Dry Tortugas, the paper should be regarded as bionomic in intention while largely systematic in form.

On account of the many new forms which are described, a key to the genera and species has been prepared, which, together with the figures, it is believed will make it possible for future workers to recognize most of the forms readily.

One trematode, *Deontacylix ovalis*, was found which I do not recognize as having any near resemblance to any family, and I have therefore made it the type of a new suborder *Deontacotylea* (figs. 231–235). I have also added the family name *Siphoderidæ* to accommodate certain trematodes with an anterior oral and a ventral genital sucker. The *Allocreadiinæ* are well represented and some very interesting problems in morphology are suggested. Prof. H. S. Pratt proposes to take up the morphological study of this and other groups. The field is certainly a rich one. Especially suggestive is the singular trematode fauna of the black angel-fish (*Pomacanthus arcuatus*), some of the genera of which bear a strong resemblance to genera which are characteristic of turtles.

Attention is here called to an interpretation of certain cells, especially abundant in the neck of many distomes, but found elsewhere less abundantly. These appear to be yolk-forming in their function. They are mentioned in the descriptions of a number of the distomes described, but the best example is that afforded by *Deradena ovalis;* see especially fig. 169.

For a cheerful readiness to compare notes and to confer upon questions of classification, I should be remiss if I did not take this opportunity of thanking Professor Pratt, who spent the season of 1909 at the Tortugas laboratory, where he began studies on the morphology of the trematodes.

I must especially express my obligations to Dr. Alfred G. Mayer, whose invitation led me to investigate the rich and interesting helminth fauna of the Dry Tortugas, and whose unfailing courtesy made my sojourn there most enjoyable.

List of Tortugas Trematodes and Their Hosts.

PARASITE.	HOST.
Aspidogaster ringens Linton	Calamus calamus.
Barisomum erubescens gen. et sp. nov	Angelichthys isabelita.
	Pomacanthus arcuatus.
	Scarus croicensis.
Brachadena pyriformis gen. et sp. nov	Calamus calamus.
	Hæmulon macrostomum.
	plumieri.
	sciurus.
Calycodes(?), immature	Caretta caretta.
Cleptodiscus reticulatus gen. et sp. nov	Pomacanthus arcuatus.
Cricocephalus delitescens Looss	Caretta caretta.
Cymatocarpus undulatus Looss	Caretta caretta.
Deontacylix ovalis gen. et sp. nov	Kyphosus sectatrix.
Deradena acuta gen. et sp. nov	Tylosurus marinus.
Deradena obtusa gen. et sp. nov	Teuthis cæruleus.
	hepatus.
Deradena ovalis gen. et sp. nov	Scarus cæruleus.
	croicensis.
	sp.
Deretrema fusillus gen. et sp. nov	Abudefduf saxatilis.
	Hæmulon macrostomum.
	Ocyurus chrysurus.
Dichadena acuta gen. et sp. nov	Teuthis cæruleus.
Dictysarca virens gen. et sp. nov	Lycodontis funebris.
	moringa.
Didymorchis latus gen. et sp. nov	Calamus calamus.
Dinurus rubeus sp. nov	Lycodontis funebris.
	moringa.
Diplangus paxillus gen. et sp. nov	Calamus calamus.
	Hæmulon macrostomum.
	plumieri.
	sciurus.
Distomum fenestratum Linton	Hæmulon plumieri.
	sciurus.
Distomum sp. (D. valdeinflatum Stossich)	Calamus calamus.
Ectenurus(?), immature	Auxis thazard.
Ectenurus virgula sp. nov	Clupanodon pseudohispanicus.
Enenterum aureum gen. et sp. nov	Kyphosus sectatrix.
Gasterostomum gracilescens Rudolphi	Lycodontis moringa.
Gasterostomum sp	Mycteroperca bonaci.
Gasterostomum sp	Mycteroperca venenosa.
Gasterostomum sp	Sphyræna barracuda.
Genolopa ampullacea gen. et sp. nov	Hæmulon plumieri.
	macrostomum.
	sciurus.
Genolopa truncata gen. et sp. nov	Hæmulon plumieri.
	sciurus.
Hamacreadium consuetum gen. et sp. nov	Hæmulon plumieri.
	sciurus.
Hamacreadium gulella gen. et sp. nov	Neomænis griseus.
Hamacreadium mutabile gen. et sp. nov	Anisotremus virginicus.
	Neomænis apodus.
	griseus.
	Ocyurus chrysurus.
	Pomacanthus arcuatus.
Hamacreadium oscitans gen. et sp. nov	Anisotremus virginicus.
	Hæmulon plumieri.
	sciurus.
Hapladena varia gen. et sp. nov	Teuthis cæruleus.
	hepatus.

Helicometra execta sp. nov	Chlorichthys bifasciatus.
	Hæmulon plumieri.
	sciurus.
	Iridio bivittatus.
	Lachnolaimus maximus.
Helicometra torta sp. nov	Epinephelus morio.
	striatus.
Helicometrina nimia gen. et sp. nov	Calamus calamus.
	Eupomacentrus leucostictus.
	Neomænis griseus.
	Ocyurus chrysurus.
Hemiurus merus sp. nov	Clupanodon pseudohispanicus.
Himasomum candidulum gen. et sp. nov	Angelichthys isabelita.
	Pomacanthus arcuatus.
Hysterolecitha rosea gen. et sp. nov	Teuthis cæruleus.
	hepatus.
Lebouria crassigula sp. nov	Calamus calamus.
Lechradena edentula gen. et sp. nov	Neomænis griseus.
Lepocreadium levenseni (Linton)	Epinephelus morio.
	striatus.
	Mycteroperca venenosa.
Lepocreadium trulla (Linton)	Calamus calamus.
	Ocyurus chrysurus.
Leurodera decora gen. et sp. nov	Anisotremus virginicus.
	Hæmulon macrostomum.
	plumieri.
	sciurus.
	Neomænis griseus.
	Teuthis hepatus.
Macradena perfecta gen. et sp. nov	Teuthis cæruleus.
Megasolena estrix gen. et sp. nov	Kyphosus sectatrix.
Mesolecitha linearis gen. et sp. nov	Teuthis cæruleus.
Mesorchis urna gen. et sp. nov	Angelichthys isabelita.
	Pomacanthus arcuatus.
Metadena crassulata gen. et sp. nov	Neomænis analis.
Microcotyle incisa sp. nov	Neomænis griseus.
Opisthadena dimidia gen. et sp. nov	Kyphosus sectatrix.
Orchidasma amphiorchis (Braun) Looss	Caretta caretta.
Pachypsolus ovalis sp. nov	Caretta caretta.
Prodistomum gracile gen. et sp. nov	Clupanodon pseudohispanicus.
Siphodera (g. n.) vinaledwardsii (Linton)	Ocyurus chrysurus.
Stegopa globosa gen. et sp. nov	Neomænis griseus.
Stephanochasmus casus sp. nov	Epinephelus striatus.
	Neomænis griseus.
	Neomænis analis.
	Ocyurus chrysurus.
Stephanochasmus sentus sp. nov	Calamus calamus.
	Hæmulon plumieri.
	sciurus.
Sterrhurus fusiformis (Lühe)	Lycodontis funebris.
	moringa.
Sterrhurus monticellii (Linton)	Abudefduf saxatilis.
	Chlorichthys bifasciatus.
	Echeneis naucrates.
	Neomænis griseus.
Theledera (g. n.) pectinata (Linton)	Auxis thazard.
Theletrum fustiforme gen. et sp. nov	Pomacanthus arcuatus.
Udonella socialis sp. nov	Neomænis griseus, on Argulus sp.
Xystretrum papillosum gen. et sp. nov	Lactophrys triqueter.

The following food notes were made as to hosts from which trematodes mentioned in this paper were obtained:

Name.	Number of hosts examined.	Food notes.
Abudefduf saxatilis	6	Character of food not recognized.
Angelichthys isabelita	3	Red sponge and associated material, worm-tubes, coralline and other vegetable material.
Anisotremus virginicus	1	Alimentary canal empty.
Auxis thazard	1	Character of food not recognized.
Calamus calamus	11	Annelids, broken shells, isopods, spines of sea-urchin.
Chlorichthys bifasciatus	4	Annelids, small arthropods.
Clupanodon pseudohispanicus	33	Small annelids.
Echeneis naucrates	2	Fragments of fish.
Epinephelus morio	7	Crabs, fish, octopus.
striatus	11	Fish, crabs.
Eupomacentrus leucostictus	3	Annelids, fragments of sea-weed.
Hæmulon macrostomum	5	Annelids, fragments of crabs, mollusks.
plumieri	169	Annelids, crustacea, fish, octopus, spines and test of sea-urchin.
sciurus	26	Annelids, crustacea, octopus, ophiurans.
Iridio bivittatus	6	Character of food not recognized.
Kyphosus sectatrix	7	Sea-weeds, small gastropods, ostracodes, isopods.
Lachnolaimus maximus	1	Broken mollusk shells and fragments of crustacea.
Lactophrys triqueter	5	Annelids in specimen in which distome was found; in others sponges and vegetable débris.
Lycodontis funebris	4	Fish and crustacea.
moringa	4	Fish.
Mycteroperca bonaci	1	Fish and crabs.
venenosa	6	Fish.
Neomænis analis	1	Crustacea.
apodus	8	Crustacea.
griseus	69	Fish, crustacea, mollusks, spines of sea-urchins, kitchen refuse.
Ocyurus chrysurus	20	Annelids, crabs, fish.
Pomacanthus arcuatus	14	Food evidently such as is browsed off the reef; mainly red sponge and associated material; sea-weed, fragments of crustacea, ascidians, annelids.
Scarus cæruleus	7	Crushed mollusk-shells, crabs, spines and test of sea-urchin, sand.
croicensis	4	Chalky material, vegetable material, and sand.
sp.	1	Chalky material.
Sphyræna barracuda	10	Fish.
Teuthis cæruleus	8	Annelids, scales of fish, vegetable débris.
hepatus	7	Crustacea, fish, sea-weed, sand.
Tylosurus marinus	1	Fish.
Caretta caretta	3	Fragments of sea-weed and Palinurus in one; vegetable débris in one; alimentary canal of the other empty.

Key to the genera and species described in this paper.

HETERACOTYLEA:
1. Body without tentacles elongate, paired anterior suckers............. 2
2. Posterior sucking-disk unarmed and without radial ridges.. *Udonella socialis*
Posterior elongated disk provided with numerous small suckers *Microcotyle incisa*

ASPIDOCOTYLEA:
Large elliptical ventral sucker with numerous depressions, no oral sucker, intestine not bifurcate; one testis; marginal sense-organs *Aspidogaster ringens*

DEONTACOTYLEA:
No suckers, mouth minute, intestine biramous, the rami with branches; genital apertures separate at posterior end; body covered with minute spines, oval.......................... *Deontacylix ovalis*

MALACOTYLEA:
1. One sucker (oral) present (MONOSTOMIDÆ)........................ 58
2. Two suckers present... 3
3. (*a*) An anterior sucker (acetabulum) and a small ventral sucker (oral) (GASTEROSTOMIDÆ).. 4
(*b*) An anterior sucker (oral) and a small ventral sucker (genital) (SIPHODERIDÆ)... 5
(*c*) An anterior sucker (oral) and the acetabulum at the posterior end (PARAMPHISTOMIDÆ)....................................... 11
(*d*) An anterior sucker (oral) and the acetabulum on the mid-ventral surface (FASCIOLIDÆ).................................. 13
4. GASTEROSTOMIDÆ. The species of the genus Gasterostomum could not be satisfactorily determined on account of the poor condition of the material. See figures 217–225.
5. SIPHODERIDÆ 6
6. Testes more than one... 8
One testis.. 7
7. Esophagus short or none, body ovate............ *Genolopa ampullacea*
Esophagus as long or longer than pharynx, body linear-oblong *Genolopa truncata*
8. Testes two.. 9
Testes more than two......................... *Siphodera vinaledwardsii*
9. Testes opposite, vitellaria compact.............................. 10
Testes tandem, uterus in front of testes vitellaria diffuse *Prodistomum gracile*
10. Ovary behind testes, body subglobular.................. *Stegopa globosa*
Ovary between testes, body short-oval.............. *Metadena crassulata*
11. PARAMPHISTOMIDÆ... 12
12. Lateral pharyngeal pockets and cirrus-sac present; no ventral papillæ; testes slightly lobed...................... *Cleptodiscus reticulatus*
13. FASCIOLIDÆ.. 14
14. Pharynx present.. 15
No pharynx (immature)......................... *Distomum fenestratum*
15. Ovary behind testes.. 45
Ovary in front of testes (beside testes in Dichadena, No. 43).......... 16
16. Vitelline glands compact...................................... 42
Vitelline glands diffuse or dendritic............................. 17
17. Body smooth.. 22
Body more or less spinose [1]....................................... 18
18. Without oral spines... 20
With oral spines... 19

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[1] Spines, both those on the body and neck and those around the mouth, are often deciduous. There may be cases therefore of really spined forms described as spineless. See for example fig. 87, which is plainly near the genus *Stephanochasmus*.

Ovary in front of testes, vitellaria diffuse, more or less spinose.

19. Neck not slender, esophagus very short..........*Stephanochasmus casus*
Neck slender, esophagus about as long as pharynx...*Stephanochasmus sentus*
20. Two testes.. 21
One testis..*Hapladena varia*
21. Body short oval, esophagus short or none, testes diagonal.*Lepocreadium trulla*
Body linear oval, esophagus distinct, testes nearly tandem
Lepocreadium levenseni

Ovary in front of testes, vitelline glands diffuse, body smooth (except in *Pachypsolus*).

22. Testes two.. 25
One testis.. 23
23. Ventral sucker larger than oral, ova large.................... 24
Suckers about equal, ova moderate.....................*Deradena ovalis*
24. Ventral sucker nearly twice diameter of oral.............*Deradena acuta*
Ventral sucker about 1.25 times oral..................*Deradena obtusa*
25. Folds of uterus extend back of one or both testes.................. 39
Folds of uterus not back of testes, at least not behind both........... 26
26. Head without appendages.................................... 29
Head with appendages...................................... 27
27. Intestinal rami not united at posterior end........................ 28
Intestinal rami united at posterior end..............*Enenterum aureum*
28. Head with short nodular papillæ and ventral flap
Immature distome related to Calycodes
Head and neck with tentacular lobes................*Theledera pectinata*
29. Seminal vesicle near anterior border of acetabulum.................. 30
Seminal vesicle behind acetabulum..................*Lechradena edentula*
30. Ova not filamented.. 33
Ova filamented.. 31
31. Vitelline glands extend into neck................................ 32
Vitelline glands behind acetabulum....................*Helicometra torta*
32. Testes irregular...................................*Helicometra execta*
Testes usually 5 right and 4 left......................*Helicometrina nimia*
33. Vitellaria extend into neck.................................... 35
Vitellaria do not extend into neck............................. 34
34. Ventral sucker larger than oral...................*Hamacreadium oscitans*
Ventral sucker smaller than oral......................*Megasolena estrix*
35. Esophagus short.. 37
Esophagus long... 36
36. Genital aperture median....................*Hamacreadium consuetum*
Genital aperture not median..................*Hamacreadium mutabile*
37. Testes diagonal, or nearly so.................................. 38
Testes opposite, or nearly so, body broad.............*Didymorchis latus*
38. Genital aperture median........................*Hamacreadium gulella*
Genital aperture not median.........................*Lebouria crassigula*
39. Folds of uterus extend back of both testes........................ 40
Folds of uterus mainly between the separated testes, but not behind the
posterior testis........................*Orchidasma amphiorchis*
40. Intestinal rami without lateral projections........................ 41
Intestinal rami with lateral projections..............*Pachypsolus ovalis*
41. Intestinal rami long...............................*Mesolecitha linearis*
Intestinal rami short..........................*Cymatocarpus undulatus*

Ovary in front of testes, vitelline glands compact.

42. Testes tandem... 43
Testes opposite... 44
43. Ovary in front of testes........................*Diplangus paxillus*
Ovary beside testis..................................*Dichadena acuta*
44. Genital aperture lateral............................*Deretrema fusillus*
Genital aperture median, body subcircular in outline, neck linear
Xystretrum papillosum

Ovary behind testes.

45. Appendiculate.. 53
Not appendiculate.. 46
46. Testes behind acetabulum.. 47
Testes in front of acetabulum, spinose....................*Mesorchis urna*
47. Seminal vesicle in front of or dorsal to acetabulum.................. 49
Seminal vesicle behind acetabulum.. 48
48. Vitelline glands with numerous lobes................*Macradena perfecta*
Vitelline glands not lobed..........................*Opisthadena dimidia*
49. Ovary in front of vitelline glands.. 50
Ovary behind vitelline glands.......................*Dictysarca virens*
50. Body without papillæ.. 51
Body with coarse papillæ in mid-ventral region ....*Theletrum fustiforme*
51. Vitelline glands not deeply lobed.. 52
Vitelline glands with long clavate lobes............*Brachadena pyriformis*
52. Vitelline glands slightly lobed, body oval..............*Leurodera decora*
Left vitelline gland deeply, right slightly lobed........*Hysterolecitha rosea*
53. Vitellaria tubular.. 56
Vitellaria not tubular.. 54
54. Body smooth.. 55
Body serrate..*Hemiurus merus*
55. Vitellaria moderately lobed.......................*Sterrhurus monticellii*
Vitellaria with about 7 long-clavate, slender lobes......*Sterrhurus fusiformis*
56. Body serrate.. 57
Body wrinkled, not serrate, greatly elongated posteriorly...*Dinurus rubeus*
57. Two dorsal eminences on neck........................*Ectenurus virgula*
No eminence evident..................*Immature distome near Ectenurus*
58. MONOSTOMIDÆ.. 59
59. Anterior end somewhat triangular, a prominent muscular ridge separating it from the rest of the body.. 60
Body boat-shape ....*Barisomum erubescens*
60. Linear oblong, posterior end truncate with 2 small, postero-lateral pits; intestinal rami with side projections........*Cricocephalus delitescens*
Linear, strap-shape; intestinal rami simple........*Himasomum candidulum*

I. TREMATODES FROM LOGGERHEAD TURTLE.

Cricocephalus delitescens Looss. (Figs. 1-3.)

Zool. Jahrb., XII, pp. 666-667, 759-762, Taf. 31, figs. 76-80.

A single specimen, actively contractile, 4 to 10 mm. in length, is referred to this species, although there are some differences between its anatomy and that of *C. delitescens* as given by Looss. Unfortunately the specimen, when stained and mounted, revealed but little of the anatomy, and it was damaged in attempting to section it later. The sketch (fig. 1) was made from the stained and mounted specimen, but a few details were added from the fragments of the damaged sections. It will be noted that the intestines lie laterad of the testes, which would point to Looss's genus *Pronocephalus*. On the other hand the presence of the peculiar structures at the lateral angles of the posterior end of the body, which are the principal justification for the erection of the genus *Cricocephalus*, are quite distinct in this specimen. The description which follows is necessarily incomplete.

Body long-oval; head blunt, triangular, marked off from the body proper by a distinct muscular eminence; posterior end truncate, with a small sucker at each lateral margin. Oral sucker a little broader than long; mouth with notch on posterior border; esophagus slender with a pharyngeal enlargement at its base and followed immediately by the bifurcation of the intestine. The intestinal rami extend to the posterior end of the body; anteriorly they have numerous short branches, but at their posterior ends, which pass laterad of the testes, the branching is not so evident. The structures at the postero-lateral angles of the body appear to be small suckers. Each sucker consists of a slight conical elevation, which, upon magnification, is seen to be shaped like a low frustum of a cone hollowed out into a shallow pit. They are surrounded by dense muscular tissue. The genital aperture is ventral at the left side of the neck and near the lateral margin. The cirrus-pouch is long and consists of three portions: proximal, middle, and distal, reckoning from the anterior end. The proximal division contains the retracted cirrus which is surrounded by prostate cells; the middle part is cylindrical and contains the convoluted seminal duct; the distal part is long oval-elliptical in outline, and contains the seminal vesicle, which also is surrounded by prostate cells. Behind the cirrus-pouch is the vas deferens, a comparatively capacious duct lying along the middle line and extending as far as the vitelline glands. The testes are 2, lateral, opposite, and near the posterior end of the body. The ovary is near the antero-median border of the right testis and is situated a little to the right of the median line. It appears to be slightly lobed. The shell-gland is on the posterior border of the ovary between the testes. The vitellaria are lateral and extend for a short distance forward from the anterior borders of the testes. Each gland consists of a cluster of irregularly rounded, compact masses. The uterus begins at the shell-gland and passes to the anterior end of the body by a series of transverse folds packed closely together and filling all of the body between the vitelline glands and the anterior third of the body. The metraterm is capacious, muscular, and lies parallel with the cirrus-pouch on its left side. The ova are long-elliptical in outline, the longer diameter being more than 2.5 times the shorter. Each ovum is provided with a single filament at one pole. In a few cases there appeared to be a filament at the other pole, but in these cases the second filament did not appear to be a prolongation of the shell as in the ordinary cases. The body-wall is thickly beset with small, granular clusters which give a mottled appearance to the surface of the specimen in balsam. These may be clusters of yolk-forming cells.

Host, *Caretta caretta:* July 1, 1906, one specimen.

Dimensions in balsam: Length 4.60; breadth 1.33; oral sucker, length 0.34, breadth 0.38; posterior pit 0.10; ova 0.029 by 0.011; length of ovum and filament 0.12.

Distomum sp., immature, related to genus Calycodes. (Figs. 4–6.)

The following description is based on a single immature specimen: Body linear, rather stout; at the anterior end there is a deeply emarginate flap which is muscular and a continuation of the wall of the oral sucker. This flap projects ventrally and overhangs the mouth like an upper lip. There appear to be 4 low, lateral papillæ on the head, one of each pair being the lateral angle of the upper lip; oral sucker nearly twice the diameter of the ventral sucker; pharynx moderate, pyriform; esophagus long; bifurcation of the intestine at the ventral sucker which is situated a little back of the middle of the length of the body. The intestinal rami are thick-walled and extend to the posterior end of the body. The specimen is too immature to permit of satisfactory identification of the rudiments of the genitalia. The genital aperture is at the anterior border of the ventral sucker. Two small bodies, median, and near the posterior end are probably rudiments of the testes. In front of the anterior of these there is another small body which presumably represents the ovary. In front of the latter there is a spiral tube which reaches to the ventral sucker and doubtless is the uterus.

Host, *Caretta caretta :* July 4, 1907, 1 specimen, immature.

Dimensions, life: Length 1.50; breadth 0.45; oral sucker 0.30; pharynx 0.08; ventral sucker 0.17; breadth of head 0.33.

Dimensions in balsam: Length 1.40; breadth 0.43; length of neck 0.66; oral sucker, length 0.24, breadth 0.28; pharynx, length 0.10, breadth 0.08; ventral sucker, length 0.14, breadth 0.15.

Pachypsolus ovalis sp. nov. (Figs. 7–14.)

Under moderate magnification this species appears to be smooth, but when more highly magnified it is seen to be covered by a peculiar layer consisting of slender, rod-like structures embedded in a fine granular matrix. This layer is rather thick and has a tendency to separate from the underlying layer, or to disintegrate. A sketch representing the species as spinose would be misleading. In cases where this layer has partly disintegrated the outline left often presents the appearance of being beset with slender rod-like or cilia-like structures. Indeed the layer when intact is not unlike in appearance to a ciliated surface. The most obvious difference between this species and *P. irroratus* (R.) Looss is to be found in the nature of the cirrus-pouch. In *P. ovalis* it is relatively short, reaching barely to the posterior edge of the acetabulum, while in *P. irroratus* it extends far back of the acetabulum between the testes.

Body compressed, thickish when at rest; outline long-oval or elliptical, in some cases oblong with extremities bluntly rounded; living specimens very active, the shape constantly changing; translucent with conspicuous excretory vessels. Oral and ventral suckers about equal, the latter about the middle of the body. Pharynx relatively large, longer than broad, joined with oral sucker by a very short prepharynx; esophagus very short, only discernible in sections. In transverse sections the lumen of the pharynx, at its anterior end, is surrounded by 4 blunt, tooth-like lobes (fig. 11). The rami of the intestines are capacious, sacculate, with thick mucous membrane composed of large, granular cells. In some preparations these cells have striated borders. The intestines extend to the posterior end of the body. Each ramus sends 2 or 3 short diverticulæ forward. The first diverticulum on each side lies beside the pharynx and extends cephalad as far as the anterior end of the pharynx. The genital aperture is immediately in front of the ventral sucker, close to its anterior border, and a little to the left of the median line. The cirrus-pouch, in most cases, lies along the anterior border and right side of the ventral sucker; the anterior portion contains the cirrus surrounded by prostate cells, the posterior portion contains the convoluted seminal vesicle. There are some variations in the position of the cirrus-pouch and of the genital aperture, as well as in the proportions of the prostate and seminal vesicle. In the majority of the cases examined the prostate occupied a little more than half the length of the cirrus-pouch, and the genital aperture was very close to the anterior border of the ventral sucker. Testes 2, opposite, lobed, close behind the ventral sucker. The ovary is subglobular, subtriangular to oval-elliptical in sections, and lies very close to the posterior border of the ventral sucker, a little to the right of the median line, in front of the right testis and close to its antero-median border. The shell-gland with the seminal receptacle on its lateral border is dorsal to the ovary. Where best seen the seminal receptacle is globular and dorsal to the posterior edge of the ovary. Laurer's canal opens dorsally opposite the posterior border of the ventral sucker and near the median line. The position of the vitellaria, as seen in the larger specimens in balsam, is lateral and dorsal from a point on a level with the anterior edge of the ventral sucker, then lateral only as far back as the posterior edge of the testes. In other cases they extend from the anterior edge of the ventral sucker or slightly in advance of that point to a point about midway between the testes and the posterior end. In sections they were seen to extend laterally nearly to the posterior end. They are diffuse and somewhat dendritic. The voluminous folds of the uterus fill the body behind the testes extending forward between the testes and dorsal to them to pass to the left of the cirrus-pouch, where, as the metraterm, it lies parallel to the cirrus-pouch and opens along with the cirrus at the genital pore. The excretory vessels, while presenting very many differences of detail, were in general as represented in the sketch (fig. 14).

They are irregularly branching and unite behind the ventral sucker. In general there are 2 main lateral branches, but with transverse connecting vessels in front of the ventral sucker and in the vicinity of the pharynx, and are confluent in the head region.

Host, *Caretta caretta:* June 29, 1907, 275 distomes, collected from the intestine of one turtle.

Some of the distomes were opaque white, thickish, and quiet; others were translucent and very active. The larger of each kind about the same size, 4 mm. in length. The smallest were without ova. One of the smaller, quiet specimens measured 1.61 in length and 0.67 in breadth. The two kinds do not differ much after they have been in alcohol.

Dimensions of one of the larger, active specimens, flattened and fixed over the flame: Length 3.8; breadth 1.6; oral sucker, length 0.56, breadth 0.64; pharynx, length 0.33, breadth 0.28; ventral sucker 0.63; ova 0.042 by 0.015.

Dimensions of another taken from sections: Length 2.76; breadth 0.84; length of neck 1; oral sucker 0.50; pharynx, length 0.28, breadth 0.21; ventral sucker 0.50; ova 0.047 by 0.020.

The ova in a small specimen, which was 1.54 in length, measured 0.030 by 0.015.

Cymatocarpus undulatus Looss. (Figs. 15–22.)

Zool. Jahrb., XII, pp. 593–594, Taf. 27, figs. 32, 33, 34.

Body moderately thick, broadest in front of ventral sucker, somewhat narrowed posterior to ventral sucker; when flattened often spatulate. Color translucent white except in uterine portion, which in adult individuals is characteristically colored by the eggs, the folds on the right side being dark-brown and those on the left side lemon-yellow. The body is covered with very dense, fine spines. Suckers about equal; ventral sucker a little in front of the middle of the body; pharynx small, adjacent to oral sucker; esophagus long and slender; intestinal rami short, divergent, clavate, not reaching the ventral sucker. Genital aperture near anterior border of ventral sucker. Copulatory apparatus large and complex. The large cirrus-pouch curves around the left side of the ventral sucker. At the base of the cirrus there are a number of small bursæ (about 4 small and 2 large) lined with fine spines. The cirrus is peculiar and difficult to understand. Besides the base, already mentioned, there is a cylindrical portion with fine, short spines and compact walls, *i.e.*, its component muscle fibers not unusually coarse. Following the cylindrical portion is a shorter, slightly enlarged portion with very coarse, circular muscle fibers. Following this and between it and the seminal vesicle there is a short, cylindrical portion with moderately strong fibers. In this portion the circular and longitudinal fibers are about the same size, giving the effect of a sieve or grating. Beyond this is an oval sac, the seminal vesicle, constricted at its distal end and with a strong wall which is continuous with the cirrus wall. The cirrus and seminal vesicle are both surrounded by the cells of the prostate and all are inclosed in the strong walls of the cirrus-pouch (figs. 15 and 16).

The testes are 2, subglobular, oval in flattened specimens, situated a short distance behind the ventral sucker and more or less diagonally placed. The ovary is in front of the left testis and close to the cirrus-pouch. On its posterior border and between it and the left testis is the oval or pyriform seminal receptacle. The shell-gland lies mediad of the ovary and seminal receptacle. Ducts from the vitellaria meet ducts from the seminal receptacle and ovary near the distal end of the cirrus-pouch. The vitellaria are somewhat racemose clustered bodies, lateral, and extending from the anterior border of the testis on the right side and from the anterior border of the ovary on the left forward to a point about half-way between the two suckers. The broad neck is filled with large nucleated, peripheral cells, and the inclosed parenchyma contains much granular material which appears in rather ill-defined spaces. I interpret these cells as yolk-forming cells, the granular material as yolk stuff, and the vitellaria as accumulated yolk (fig. 22). Beginning with the shell-gland the uterus passes between the testes, its voluminous folds filling the left side of the body behind the testes and returning by equally voluminous folds on the right side. Again passing between the testes it turns to the right and passing along the right side of the ventral sucker it expands into the capacious and muscular metraterm which is surrounded by glandular cells and opens with the cirrus at the genital pore. The main excretory vessel was seen in sections to begin dorsal to the pharynx, where it occurred in 1 section. In the 9 succeeding sections the excretory vessel appeared as a vertical slit beside the esophagus. It then passed to the ventral side of the esophagus whence it continued, in 6 sections, to the bifurcation of the intestine (figs. 18 and 19). In the next 3 sections it passed dorsally between the intestinal rami. Thence it passed on the dorsal side of the cirrus-pouch, then descending a little to lie directly on the ventral sucker. It then passed ventrad to the posterior end of the cirrus-pouch and seminal vesicle, between the testes, then dorsal to the folds of the uterus, where for a time it was indistinct because its walls were pressed close together by the distended uterus Toward the posterior end it became more distinct again and was traced to the terminal excretory pore which is guarded by a number of triangular valve-like flaps (fig. 21) The same sequence was found in two other sets of transverse sections. The nature of the excretory system presents the only important difference between my specimens and Looss's species.

Host, *Caretta caretta:*

1906, July 1, very numerous, approximately 3,000.
1907, June 29, 130; July 4, numerous.

The following note is extracted from notes made at the time of collecting: On July 1 the stomach and intestine of a loggerhead turtle were examined. There was no food, but the mucous membrane of the intestine as far as the rectum was thickly peppered with small, black spots which proved to be small distomes. There were about 50 to the square inch in a surface 18 inches long by 3 inches broad. The dark color is due to the eggs which are collected in a mass at the posterior end of the distome. Specimens which had lain in sea-water overnight and were somewhat flaccid were measured after they had been flattened under the cover-glass. The longest were 5.5 mm. in length and 2 mm. in breadth; the smallest 2 by 1 mm. More detailed dimensions of the larger specimen are: Length 5.5, breadth 2; breadth, through anterior sucker 1, between suckers 1.8, at ventral sucker 1.5, between ventral sucker and posterior end 1.4, near posterior end 0.7; oral sucker, length 0.28, breadth 0.30; pharynx 0.11; ventral sucker 0.28; distance from oral sucker to forks of intestine 1.9; length of rami of intestine 0.7; greatest breadth of intestine 0.25; ova 0.024 by 0.012.

Orchidasma amphiorchis (Braun) Looss. (Figs. 23–28.)

Braun, Mitt. a. d. Zool. Mus. Berlin, Bd. II, 1901, p. 20, Taf. 1, figs. 7, 11.
Looss, Centralbl. f. Bak., Par. u. Infek., Bd., XXX, 1901, p. 560; Zool. Jahrb., XVI, 1902, pp. 500, 502.

Body of various shapes, but prevailingly linear, sometimes vase-shape, usually rounded in front and slightly contracted back of the head, posterior end narrowing to a blunt point, anterior end densely covered with short spines. Oral sucker about twice the diameter of the rather weak ventral sucker; pharynx a little less than half the diameter of the oral sucker, its length about equaling its breadth. There is a short prepharynx and an esophagus about equal in length to the pharynx. Intestinal rami with rather thick walls and extending to the posterior end of the body. Genital aperture on median line at anterior edge of ventral sucker. Cirrus-pouch very long, the retracted cirrus lying in convoluted folds behind the ventral sucker. It is thickly beset with relatively large spines. Testes 2, small, subglobular, remote from each other, with folds of the uterus between them. One testis is near the posterior end of the body, the other a little behind the middle. Seminal vesicle inclosed in cirrus-pouch at its distal end. Cirrus surrounded by prostatic cells. Ovary small, lying close to antero-dorsal surface of anterior testis. In most cases it can be seen only in dorsal view. Seminal receptacle dorsal to anterior testis and protruding beyond its right anterior edge. Shell-gland on medial side of seminal receptacle. Vitelline glands marginal, extending from anterior testis, or a little in front of it, to the anterior edge of the ventral sucker or not quite so far, made up of small, subglobular bodies. The folds of the uterus lie between the testes and in front of the anterior testis. The uterus ends in a capacious, muscular metraterm, which, like the cirrus, is lined with relatively large spines. These spines are larger at the distal end than they are near the genital aperture. The spines in both cirrus and metraterm have basal supports. Ova small, short-oval or circular in outline, with thick shells.

In some of the mounted specimens there were numerous, dark-colored, slender, bristle-like structures in the lumen of both the cirrus and metraterm.

Dimensions in balsam.

Length	2.31	2.46	2.66	1.42
Breadth	0.63	0.37	0.45	0.58
Oral sucker	0.33	0.28	0.32	0.25
Ventral sucker	0.16	0.14	0.16	0.16
Pharynx	0.13	0.11	0.12	0.11

Dimensions of ova: 0.034 by 0.040; 0.037 by 0.030; 0.040 by 0.040. Thickness of shell 0.0034.

Host, *Caretta caretta:* June 29, 1907, 12 specimens, in stomach.

II. TREMATODES FROM FISH.

MALACOTYLEA.

FASCIOLIDÆ.

Comparative table of the Allocreadiinæ described in this paper.

	Shape.	Length.	Breadth.	Oral sucker.	Pharynx.	Ventral sucker.	Ratio of neck to length.	Esophagus.
Helicometra torta	Oval........	1.18 to 3.08	0.05 to 0.77	0.18	0.11	0.40	¼ ±	=ph.+
Helicometra execta.	Linear, oval, pyrif., etc.	0.43 to 2.45	0.27 to 0.70	0.17	0.10	0.21	⅓ ±	=ph.+
Helicometrina nimia.	Oval, fusiform, etc.	1.04 to 2.46	0.58 to 0.91	0.15	0.08	0.29	⅓ −	=ph.+
Hamacreadium mutabile.	Various......	1.5 to 4; 5.5 max., life.	0.98	0.22	0.15	0.33	⅓ −	=ph.+
Hamacreadium gulella.	Oval.........	1.85	0.67	0.15	0.08	0.24	⅓ +	short.
Hamacreadium consuetum.	Ovate........	0.77 to 1.61	0.46	0.15	0.06	0.21	⅓ −	=ph.+
Hamacreadium oscitans.	Oval.........	1.37	0.48	0.15	0.07	0.43	⅓ +	=ph.+
Lebouria crassigula.	Oval-elliptical.	1.54	0.66	0.25	0.15	0.35	⅓ +	short.

	Genital aperture.	Prostatic cells.	Ovary.	Testes.	Yolk-glands.	Ova.
Helicometra torta.	Median.	Many.	About 3-lobed	2 diagonal, faintly lobed.	To uterus...	0.06 by 0.03 filamented.
Helicometra execta.	Median.	Many.	About 4- to 5-lobed.	Variable.......	About to pharynx.	0.05 by 0.03 filamented.
Helicometrina nimia.	Median.	Few..	Much lobed...	Usually 5 right and 4 left.	To fork of intest.	0.05 by 0.03 filamented.
Hamacreadium mutabile.	Left....	Many.	Much lobed...	2 diagonal, slightly lobed.	To fork of intest.	0.078 by 0.051
Hamacreadium gulella.	Median.	Few...	About 4-lobed	2 oval, diagonal.	To fork of intest.	0.078 by 0.044.
Hamacreadium consuetum.	Median.	Many.	Lobed variable.	2 oval, diagonal.	To pharynx.	0.052 by 0.039.
Hamacreadium oscitans.	Median.	Few...	About 4-lobed	2 oval, diagonal.	To ventral sucker.	0.044 by 0.031.
Lebouria crassigula.	Left....	Few...	Oval.........	2 oval, diagonal.	To oral sucker.	0.07 by 0.04.

Helicometra torta sp. nov. (Figs. 29–33.)

Body oval or long oval, often folded or crumpled and yellowish green in life; neck rather short in preserved specimens; ventral sucker 2 to 2.5 times the diameter of the oral sucker, usually with its aperture longitudinal; oral sucker usually nearly circular in outline, but ventral sucker in most cases longer than broad. There is a short prepharynx. The pharynx is somewhat variable, in some cases about as broad as long, in others cylindrical and much longer than broad. The esophagus is slender and as long or longer than the pharynx. The intestinal rami extend to the posterior end of the body. Reproductive aperture median, near the posterior end of the pharynx. The cirrus-pouch passes dorsad and caudad, its basal portion containing the seminal vesicle and lying dorsal to the anterior border of the ventral sucker, or, in contracted specimens, along the right border of the ventral sucker. The prostate gland is represented by many cells inside the cirrus-pouch, around the ejaculatory duct and folds of the seminal vesicle. The testes are 2, close together, one behind the other, or very slightly diagonal, oval, or, under pressure, more or less lobed. Ovary close to anterior border of anterior testis, a little to the right side, lobed, especially on the posterior border, where usually about 3 lobes can be distinguished. A yolk-reservoir, in most cases pyriform in shape, lies dorsal and in front of the ovary, and a seminal receptacle in front of the yolk-reservoir toward the left side. The vitelline glands are diffuse masses along the margins from the posterior end to the posterior folds of the uterus, and in two rows behind the posterior testis, one on each side of the median line; uterus in close wreath-like folds between the ovary and the ventral sucker. The ova are arranged in orderly fashion, the filaments being joined in such a way as to make it appear that the ova are so many beads pendent from a supporting cord. The excretory vessel is not evident in the mounted specimens, but was noted in life to be a conspicuous, dark-brown vessel extending from the posterior end of the body to the ovary.

The following measurements are from 6 specimens mounted in balsam:

Length.	Maximum breadth.	Length of neck.	Diameter of oral sucker.	Diameter of pharynx.	Diameter of ventral sucker.
3.08	0.77	0.77	0.18	0.11	0.40
2.38	0.75	0.35	0.17	0.08	0.35
2.10	0.50	0.34	0.15	0.06	0.35
1.76	0.56	0.43	0.14	0.06	0.28
1.54	0.53	0.43	0.12	0.06	0.28
1.18	0.50	0.35	0.14	0.06	0.30

The diameters given are transverse.

The ova are about 0.06 by 0.03 mm. Filaments in living specimens 0.17 mm. in length.

Some details of the anatomy of this species will be found in the figures. An interesting feature is shown in fig. 33, viz., the peculiar shape of the germ cells when they are mature and ready to enter the ootype.

This species was found in the following hosts:

Host, *Epinephelus striatus:* 1906, July 7, 3 fish examined; 1 distome.

Dimensions, flattened: Length 3.15; breadth anterior 0.35, middle 0.98, posterior 0.63; diameter oral sucker 0.23, pharynx 0.18, ventral sucker 0.51; ova 0.047 by 0.023; length of filament 0.17.

1906, July 8, 1 fish, 3 distomes; July 12, 2 fish, few distomes; July 13, 1 fish, 8 distomes.

1907, July 2, 1 fish, 8 distomes; July 8, 1 fish, 2 distomes.

Host *Epinephelus morio:*

1907, July 4, 1 fish, 4 distomes; July 8, 1 fish, 2 distomes.

1908, June 28, 1 fish, 2 distomes; June 30, 1 fish, 6 distomes; July 1, 2 fish, 3 distomes; July 3, 1 fish, 5 distomes.

Dimensions of one flattened: Length 2.17; breadth 1.08; diameter of oral sucker 0.23; pharynx 0.11; ventral sucker 0.50; ova, exclusive of filament, 0.054 by 0.027.

Helicometra execta sp. nov. (Figs. 34-39.)

Body variously shaped, linear, oval to pyriform; ventral sucker from 1.25 to twice the diameter of the oral sucker; pharynx subglobular, preceded by a very short prepharynx; esophagus relatively long; intestinal rami extend to near the posterior end; genital aperture median, at bifurcation of the intestines; cirrus-pouch cylindrical, median, or its posterior end deflected to the right. In any case the principal length of the cirrus-pouch is in front of the ventral sucker; prostate represented by many cells which surround the ejaculatory duct. Testes variable; in some specimens they were not present; in others they were represented only by loose aggregations of testicular cells, as if the organ was almost spent. In those individuals in which testes were present there was little uniformity. In some there was but one testis, which corresponded in appearance and position with the left anterior testis of *Helicometrina nimia.* In other cases (figs. 38*a*, 38*d*) there was a single median testis immediately behind the ovary. In others no testis was present (fig. 38*c*). This figure was drawn from the ovary of one of the largest mounted specimens in my collection, 2.45 mm. in length. The specimen is stained and mounted in balsam and shows the details of structure very well. The testes have entirely disappeared. The ovary is lobed; usually 4 or 5 lobes can be made out. It lies transversely about half-way between the ventral sucker and the posterior end. Anterior and dorsal to the ovary is a transversely placed yolk-reservoir which receives ducts from each side, and dorsal to this is the seminal receptacle. The shell-gland lies on the anterior and dorsal border of the ovary. The vitelline glands are diffuse, posterior, and marginal, and extend forward about to the pharynx. Behind the ovary they tend to form 4 parallel, longitudinal rows, the 2 on one side of the median line being separated from each other by the intestine, and the 2 median rows having the excretory vessel between them. The wreath-like folds of the uterus lie between the ovary and the ventral sucker. Each ovum is provided with a long filament and their arrangement in the uterus is similar to that of *Helicometra torta.* The excretory vessel is inconspicuous in the mounted specimens. It appears to be essentially like that of the preceding species.

Following are measurements of specimens mounted in balsam:

I. From *Hæmulon plumieri.*

Length.	Breadth.	Length of neck.	Diameter of oral sucker.	Diameter of pharynx.	Diameter of ventral sucker.	Dimensions of ova.
2.45	0.70	0.80	0.17	0.10	0.21	
2.03	0.70	0.73	0.18	0.10	0.28	
1.65	0.56	0.56	0.14	0.08	0.27	0.051: 0.031
1.47	0.56	0.52	0.14	0.07	0.24	
1.40	0.63	0.70	0.13	0.07	0.24	0.051: 0.034
1.40	0.56	0.56	0.14	0.07	0.21	
1.04	0.36	0.38	0.10	0.08	0.22	

II. From *Chlorichthys bifasciatus.*

1.00	0.46	0.36	....	....	0.17	0.054: 0.027
0.72	0.31	0.28	0.08	0.04	0.13	
0.70	0.35	0.26	0.11	0.06	0.17	0.050: 0.024
0.50	0.21	0.22	0.06	0.03	0.13	0.051: 0.027
0.43	0.21	0.21	0.06	0.03	0.13	0.051: 0.027

It will be observed that the most striking difference between this and the preceding species is in the character of the testes, the greater anterior prolongation of the vitelline glands, and the range in size. In this species adults with ova range from 1 mm. to 2.45 mm., while those from *Chlorichthys* are all small, varying from 0.43 to 1 mm. in length. The difference in size between the distomes from these two hosts is very marked. This leads to a decided difference in appearance. In the small distomes the number of ova is very few, while the size of the ova remains the same as in the larger distomes from *Hæmulon.* I do not feel justified at present in placing them in different species, but prefer rather to regard the differences as due to the fact that they are living in hosts which are not closely related.

Variability of Testes.—Five of these small distomes were examined, with the following result: (1) 1 testis, median; (2) no testis seen, (3) 1 testis, median; (4) 2 testes, 1 left, 1 right; (5) 1 testis, transverse, faintly bilobed. The cells of the testes were loosely clustered as if the organs were disintegrating. Ovary variously lobed.

This species was found in the following hosts:

Host, *Hæmulon plumieri:*

1906, July 5, 6 fish, 7 distomes; July 15, 1 fish, 9 distomes; July 13, 2 fish, 1 distome.

1907, June 28, 2 fish, few distomes; July 3 and 4, 16 fish, many distomes; July 10, 12 fish, few distomes; July 13, 6 fish, few distomes.

1908, July 1, 7 fish, few distomes; July 14, 14 fish, few distomes.

Dimensions in life, flattened: Length 1.54, breadth 0.75; diameter of oral sucker 0.14, pharynx 0.07, ventral sucker 0.25; ova 0.048 by 0.027 excluding filament.

Host, *Hæmulon sciurus:*

1907, June 28, 1 fish, few distomes; July 12, 3 fish, 1 distome.

Host, *Chlorichthys bifasciatus:*

1907, July 1, 1 fish, 4 distomes; July 8, 1 fish, 2 distomes.

Various shapes, linear to pyriform. Dimensions, life: Length 0.73, breadth 0.23; diameter oral sucker 0.07, ventral sucker 0.14; ova 0.056 by 0.028. Another, length 1.15, breadth 0.45, pharynx 0.07, oral sucker 0.13, ventral sucker, 0.22; ova 0.054 by 0.027.

Host, *Iridio bivittatus:* June 28, 1907, 6 fish, few distomes.

These were small, pyriform with slender neck in some, oval when compressed. Dimensions, life, flattened: Length 1.22, breadth 0.59, oral sucker 0.11, pharynx 0.08, ventral sucker 0.28; ova 0.042 by 0.018; length of filaments about 0.18.

Host, *Lachnolaimus maximus:* July 18, 1906, 1 fish, 1 distome.

Helicometrina nimia gen. et sp. nov. (Figs. 40–48.)

I have adopted a suggestion made to me by Professor Pratt that this form be placed in a new genus, but at the same time giving it a name that would remind one of the genus *Helicometra.*

Body oval, but assuming various contraction shapes, fusiform, pyriform, etc., slightly nodular on head and neck; ventral sucker about 1.5 times the diameter of the oral sucker; neck one-third or more the length of the body. There is a short prepharynx and the pharynx is longer than broad; esophagus relatively long; genital aperture median, just behind the bifurcation of the intestine; cirrus-pouch clavate, inclosing the tubular and convoluted seminal vesicle in its basal portion. The cirrus-pouch may be wholly median, its base slightly overlapping the anterior edge of the ventral sucker, or the base may lie along the antero-lateral margin of the ventral sucker either on the right or the left side. The prostate is represented by a few cells in the anterior portion of the cirrus-pouch. Testes normally 9, usually in two longitudinal rows, one row on each side of the median line in the posterior part of the body, 5 testes on the right side and 4 on the left. A few variations from this order are noted below. Ovary median, ventral, and much lobed, in part, at least, between the two anterior testes. A yolk-reservoir lies dorsal and a little in front of the ovary, and a seminal receptacle on its right anterior border. The vitelline glands are diffuse and lateral from the posterior end to the bifurcation of the intestine, or a little in front of that point. The wreathed folds of the uterus lie between the ovary and the ventral sucker. The ova are filamented. The excretory vessel is not distinct in the mounted specimens, but was noted in the living specimens as a conspicuous median vessel extending from the posterior end, where it may be greatly inflated, along the median line as far as the ovary.

While the testes are usually arranged in two longitudinal rows, 5 on the right side and 4 on the left, one was noted with 4 on the right side and 5 on the left (44*c*). Another was seen with 4 on the right and 5 on the left, the extra testis being at the level of the second where there were 2 transversely placed instead of 1 (44*b*). A similar doubling was noted in another, where the last two testes on the right side were transversely placed (44*d*).

Dimensions of specimens mounted in balsam.

Length.	Breadth.	Neck.	Oral sucker.	Pharynx.	Ventral sucker.
2.46	0.91	0.90	0.15	0.10: 0.08	0.29
2.31	0.77	0.84	0.14	0.10: 0.07	0.25
2.17	0.72	0.80	0.14	0.10: 0.07	0.25
2.06	0.77	0.63	0.17	0.11: 0.08	0.28
2.00	0.77	0.70	0.18	0.10: 0.08	0.24
1.96	0.61	0.70	0.13	0.10: 0.07	0.21
1.90	0.63	0.71	0.14	0.10: 0.07	0.25
1.78	0.71	0.63	0.14	0.08: 0.07	0.21
1.51	0.60	0.57	0.15	0.11: 0.06	0.22
1.43	0.38	0.65	0.10	0.06: 0.05	0.18
1.04	0.58	0.42	0.13	0.07: 0.06	0.17

The cirrus-pouch was on the right side of the ventral sucker in 4, on the left side in 1, median in 5, right central in 1, and right median in 1.

The testes were 5 right and 4 left in 8 out of the 11, in the other 3 they were 4 right and 5 left. The length of the ova, exclusive of the filament, is about 0.05 and the diameter 0.03 mm.

This species was found in the following hosts:

Host, *Neomænis griseus:*

1906, July 5, 11 fish, few distomes; July 9, 14 fish, few distomes; July 10, 4 fish, few distomes; July 16, 4 fish, few distomes.

1907, July 7, 4 fish, few distomes; July 9, 5 fish, 7 distomes; July 14, 4 fish, 2 distomes; July 15, 5 fish, few distomes.

Host, *Ocyurus chrysurus:*

1907, July 10, 3 fish, 1 distome.

1908, June 30, 3 fish, 1 distome; July 4, 1 fish, 3 distomes.

Host, *Calamus calamus:* July 10, 1907, 2 fish, 1 distome.

Host, *Eupomacentrus leucostictus:* July 2, 1908, 1 fish, 2 distomes.

HAMACREADIUM gen. nov.

Etymology: ἅμα, together with; κρεάδιον, a morsel of meat.

Generic characters: Ventral sucker larger than oral; vitelline glands diffuse, posterior, and lateral; testes 2, diagonal; cirrus-pouch in front of ventral sucker, its base overlapping the ventral sucker for a short distance, or deflected on the right or left anterior border of the ventral sucker; ovary in front of testes, or on right side of anterior testis, lobed; seminal vesicle inclosed in cirrus-pouch; seminal receptacle dorsal to ovary; uterus usually entirely in front of ovary.

Hamacreadium mutabile gen. et sp. nov. (Figs. 49–54.)

Body of great variety of shapes, long-oval under compression, broadest and often emarginate at posterior end, tapering to anterior end; head and neck sparsely nodular; ventral sucker usually about 1.5 times the diameter of oral sucker; pharynx separated from oral sucker by a short prepharynx; esophagus long and slender; intestinal rami extend to posterior end of body. Genital aperture a short distance in front of the ventral sucker, on the left side of the median line; prostate cells clustered around the ejaculatory duct, most abundant near the genital aperture; cirrus-pouch cylindrical, inclosing the seminal vesicle and lying on the anterior border of the ventral sucker, often extending along the right border of the ventral sucker. Testes 2, in some slightly lobed, in others the lobation was not evident, largely on account of the obscuration caused by the vitelline glands. In some specimens which had been killed under pressure the testes were distinctly lobed. The testes are near together and diagonally placed, in some cases about half-way between the ventral sucker and the posterior end, in other cases they are nearer the posterior end. Ovary much lobed, in front of right testis, the seminal vesicle lying on its dorsal side. The vitelline glands are diffuse, on margins and behind testes, and extend into the neck a little in front of the bifurcation of the intestines. Uterus between the ovary and ventral sucker; ova relatively large. The excretory vessels are not distinct in the mounted specimens. In living specimens a large median vessel was seen. It was dark in color, extended from the posterior end, and terminated abruptly in front of the cirrus-pouch.

Dimensions of a specimen from *Neomænis griseus*, life, flattened: Length 4; breadth, anterior 0.37, middle 0.98, posterior 0.93; oral sucker, length 0.22, breadth 0.26; pharynx, globular, 0.15; ventral sucker 0.33; ova 0.078 by 0.051.

Dimensions of a specimen with triangular outline and emarginate posterior end, balsam: Length 2.30; breadth 0.94; neck 1.12; oral sucker 0.24; pharynx 0.11; ventral sucker 0.34; ova 0.075 by 0.034.

Another with similar outline but with the posterior end bluntly rounded: Length 3.02; breadth 0.77; neck 1.50; oral sucker 0.22; pharynx 0.08; ventral sucker 0.32; ova 0.075 by 0.034.

In life the active specimens are flat and leaf-like, and greenish-yellow, especially by transmitted light. The active specimens are elongated and taper anteriorly. Others, not active, are thick, squarish, opaque, and white.

This species was found in the following hosts:

Host, *Neomænis griseus:*

1906, July 5, 11 fish, numerous distomes; July 7, 4 fish, 4 distomes, length of one of largest 5.5 mm.; July 9, 14 fish, 27 distomes; July 10, 4 fish, 4 distomes; July 16, 4 fish, 4 distomes.

1907, July 7, 4 fish, numerous distomes; July 9, 5 fish, numerous distomes.

1908, July 1, 1 fish, 13 distomes; July 4, 1 fish, 50 distomes; July 12, 4 fish, few distomes; July 14, 4 fish, 9 distomes.

Host, *Neomænis apodus:*

1907, July 1, 2 fish, 1 distome, immature; July 3, 4 fish, 20 distomes, mature and immature; July 9, 2 fish, 12 distomes, immature, with conspicuous excretory vessel, dark-brown; July 11, 1 fish, 1 distome, immature.

Host, *Anisotremus virginicus:* July 6, 1907, 1 fish, 1 distome.

Host, *Ocyurus chrysurus:* July 10, 1907, 1 fish, 1 distome, immature.

Host, *Pomacanthus arcuatus:* July 3, 1907, 1 fish, 1 distome, immature.

Hamacreadium gulella gen. et sp. nov. (Fig. 55.)

Here are described two distomes which were found with a lot of the preceding species from *Neomænis griseus* (*Hamacreadium mutabile*) probably collected on July 4, 1908. They were not noticed to be different from the other species at the time of collecting.

Body oval, the greatest diameter behind the ventral sucker and tapering gradually to the anterior end; mouth subterminal; neck more than one-third the entire length; ventral sucker more than 1.5 times the diameter of the oral sucker; pharynx separated from the oral sucker by a short prepharynx; esophagus very short. The intestinal rami appear to extend to the posterior end. Genital aperture in front of ventral sucker, about half-way between it and the bifurcation of the intestines, median (in one of the worms it is nearly as far forward as the bifurcation). The cirrus-pouch inclosed the scanty prostate cells and the seminal vesicle, its base overlapping the anterior edge of the ventral sucker. The metraterm lies on the left side of the cirrus-pouch. Testes 2, oval, about half-way between the ventral sucker and the posterior end, diagonally placed and near together. Ovary about 4-lobed on right of median line near right anterior border of anterior testis. Vitelline glands diffuse, somewhat scattered, behind testes, and marginal to about the level of the bifurcation of the intestines. Uterus between anterior testis and ventral sucker; ova large. Excretory vessel a straight, median tube from the posterior end to caudal edge of ovary where it divides, the 2 lateral branches reaching the level of the pharynx. Numerous anastomosing vessels surround the oral sucker (fig. 55 *exv*).

Dimensions in balsam: Length 1.85; breadth 0.67; neck 0.71; oral sucker 0.15; pharynx 0.08; ventral sucker 0.24; ova 0.078 by 0.044.

Hamacreadium consuetum gen. et sp. nov. (Figs. 56–59.)

Body ovate, flattened, oral sucker subterminal, pharynx adjacent to oral sucker; esophagus usually as long as pharynx or longer; intestinal rami extend to the posterior end of the body; ventral sucker 1.5 times the diameter of the oral sucker, or more. Neck approximately one-third the entire length. Reproductive aperture median, immediately behind the bifurcation of the intestines. Cirrus-pouch overlaps anterior edge of ventral sucker, or it may pass for a short distance to one side, usually the right, but it was not seen to reach as far as the middle of the ventral sucker. The seminal vesicle and prostate gland are both inclosed in the cirrus-pouch. Testes 2, oval, one diagonally behind the other on opposite sides of the median line, about midway between the ventral sucker and the posterior end. Ovary lobed, somewhat variable, near anterior border of posterior testis, with the oval seminal receptacle on its dorsal surface, in some cases extending much beyond the anterior border of the ovary. Vitelline glands diffuse, along margins as far forward as the pharynx. Folds of the uterus between the testes and the ventral sucker. The metraterm passes to the left of the cirrus-pouch to the genital aperture; ova relatively large with a tubercle at one pole.

The principal variations noted in the distomes referred to this species were in the position of the cirrus-pouch and in the outlines of the ovary. The cirrus-pouch in worms which were well extended lay in front of the ventral sucker with the posterior end but slightly overlapping. In those which were more or less contracted the cirrus-pouch lay at one side of the anterior border of the ventral sucker, but did not extend as far as the middle of that organ. The ovary is sometimes difficult to make out on account of the dense masses of yolk-gland which often overlie it. In some it appeared to be bilobed, but usually deeper focussing or viewing from the opposite side brought another lobe into view. In one specimen there were as many as 5 lobes visible. The seminal receptacle is dorsal to the ovary, as shown in the figure, and extends much in advance of the ovary. This was the case in the 5-lobed ovary.

Some are much more broadly ovate than the one shown in fig. 56. This was particularly true in specimens from *Hæmulon sciurus*. In these, moreover, the ovary, while lobed, had a tendency to be elongated and to lie with its long axis inclined to the axis of the body. In some the testes are relatively nearer the posterior end than they are in the one figured.

Mounted specimens, with ova, vary from 0.77 to 1.61 mm. in length.

Dimensions of specimen in balsam: Length 1.55; breadth 0.46; oral sucker 0.15; pharynx 0.06; ventral sucker 0.27; ova 0.052 by 0.039; length of neck 0.56.

This species was found in the following hosts:

Host, *Hæmulon plumieri:*

1906, July 5, 6 fish, few distomes; July 13, 2 fish, 1 distome; July 15, 1 fish, 1 distome.

1907, July 3, 16 fish, few distomes; July 12, 12 fish, few distomes.

1908, July 9, 3 fish, 3 distomes.

Host, *Hæmulon sciurus:* 1908, July 5, 6 fish, few distomes.

Dimensions, life, flattened: Length 1.37; breadth 0.63; oral sucker 0.17; pharynx 0.06; ventral sucker 0.32; ova 0.051 by 0.034.

Dimensions, life, of a specimen from *H. plumieri:* Length 1.90; breadth 0.70; oral sucker 0.22; pharynx 0.08; ventral sucker 0.36; ova 0.051 by 0.034.

Hamacreadium oscitans gen. et sp. nov. (Figs. 61-63a.)

Body oval, usually broadest a short distance back of ventral sucker and tapering scarcely at all at the posterior end; neck bluntly conical, about equal to one-third the entire length. In some the greatest thickness is at the ventral sucker. The ventral sucker is rather more than 1.5 times the diameter of the oral sucker; pharynx close to oral sucker; esophagus about as long as the pharynx; intestinal rami extend to the posterior end. Genital aperture median at the bifurcation of the intestine; cirrus short, the small prostate and seminal vesicle inclosed in the cirrus-pouch which lies in front of the ventral sucker, its basal end overlapping the ventral sucker a very little. The testes are 2, close together, diagonally placed, about half-way between the ventral sucker and the posterior end, not lobed. The ovary is about 4-lobed and is on the right side at the anterior border of the right testis. The seminal receptacle is on the dorsal side of the ovary. The vitelline glands are diffuse, densely packed behind the testes, marginal to the posterior edge of the ventral sucker. The uterus is between the ventral sucker and the testes and ovary; ova with small tubercle at one pole. The metraterm lies on the left side of the cirrus-pouch. The excretory vessels were not seen.

This species was found in the following hosts:

Host, *Hæmulon plumieri:*

1907, July 4, 8 fish, 1 distome; July 5, 12 fish, 1 distome.

1908, July 6, 5 fish, 1 distome; July 10, 12 fish, few distomes.

Dimensions, balsam: Length 1.37; breadth 0.48; neck 0.43; oral sucker 0.15; pharynx 0.07; ventral sucker 0.43; ova 0.044 by 0.031.

Host, *Hæmulon sciurus:*

1907, July 5, 6 fish, few distomes.

Dimensions, balsam: Length 1.40; breadth 0.70; neck 0.33; oral sucker 0.16; pharynx 0.07; ventral sucker 0.31; ova 0.046 by 0.027.

Host, *Anisotremus virginicus:* July 6, 1907, 1 fish, 2 distomes.

Dimensions in balsam: Length 1.29; breadth 0.59; neck 0.48; oral sucker 0.17; pharynx 0.07; ventral sucker 0.31; ova 0.041 by 0.027.

Lebouria crassigula sp. nov. (Fig. 60.)

This species resembles *Lebouria idonea* Nicol, but the habit is more stocky than in that species, and the dense vitellaria meet in front of the intestinal bifurcation.

Body short oval or oval-elliptical; diameter of ventral sucker 1.25 to 1.33 times that of the oral sucker; pharynx relatively large; esophagus apparently very short; intestinal rami not distinctly seen but appear to reach to the posterior end; genital aperture a short distance in front of the ventral sucker on left side of the median line; cirrus-pouch nearly cylindrical, lying along the anterior and right antero-lateral border of the ventral sucker, the seminal vesicle being included in its basal portion; prostate cells few, mainly anterior to the seminal vesicle; metraterm on left side of the cirrus-pouch. Testes 2, near together on the median line, little if any diagonal, and near the posterior end of the body, oval. Ovary oval, on right side of the median line a short distance in front of the testes; seminal receptacle dorsal to the ovary and projecting caudad of its posterior border; vitelline glands very dense, obscuring the intestines, posterior and lateral, extending forward to the posterior edge of the oral sucker and meeting in front of the intestinal bifurcation; uterus between testes and ventral sucker; ova large.

Host, *Calamus calamus:*

1907, July 6, 1 fish, 1 distome, immature.

1908, June 28, 2 fish, 1 distome; July 8, 5 fish, 2 distomes.

Dimensions, life: Length 1.54; breadth 0.66; oral sucker 0.25; pharynx 0.15; ventral sucker 0.35; ova 0.068 by 0.040.

Dimensions of another, in balsam: Length 1.33, breadth 0.52, neck 0.53; oral sucker 0.24; pharynx 0.15; ventral sucker 0.29; ova 0.07 by 0.04.

Megasolena estrix gen. et sp. nov. (Fig. 64.)

Etymology: μέγας, large; σωλήν, pipe.

Body nearly linear in outline, tapering slightly at posterior end and abruptly truncate anteriorly. Mouth nearly terminal, oral sucker and pharynx about same size and each larger than the ventral sucker. The musculature of the ventral sucker is weak, while that of the oral sucker and pharynx is strong. Genital aperture in front of ventral sucker; cirrus-pouch with relatively thick wall and inclosing the short cirrus and seminal receptacle. It lies in front of the ventral sucker. The prostate lies alongside the cirrus-pouch and extends posteriorly on the right side of the ventral sucker. The cirrus-pouch is contiguous with the anterior border and the prostate extends to about the middle of the ventral sucker. There is a distinct prepharynx and an esophagus which is longer than the pharynx. The bifurcation of the intestine is dorsal to the ventral sucker and the rami extend to the posterior end. The prepharynx, pharynx, esophagus, and intestines are all relatively large. The ovary is small, subspherical, situated near the median line, a little to the right and a short distance behind the ventral sucker. The shell-gland lies on the antero-dorsal border of the ovary and the seminal receptacle a little in front of the ovary and to the right of the shell-gland. The testes were subglobular in life, ovate-elliptical in the mounted specimen. They lie close together on the median line, one behind the other, a short distance back of the ovary. The vitelline glands are diffuse and occupy nearly the whole space marginal and posterior to the ovary and testes, but do not extend quite as far forward as the posterior border of the ventral sucker. The ova are few, relatively large, and lie between the anterior testes and the ventral sucker. The metraterm passes dorsad of the cirrus-pouch and opens at the common genital aperture. The excretory vessel was not seen, but two patches of fine granular, black pigment lying lateral to the prepharynx are probably in the lateral excretory vessels of the neck.

Host, *Kyphosus sectatrix:* July 5, 1908, 1 distome.

Dimensions in life: Length 3; breadth 0.83; diameter of oral sucker 0.38, pharynx 0.38, ventral sucker 0.28; ova 0.06 by 0.03.

Didymorchis latus gen. et sp. nov. (Figs. 65, 65a.)

Etymology: δίδυμος, twin; ὄρχις, testicle.

Body broad-oval, nearly as broad as long, or breadth equal to about three-fourths of length; the diameter of ventral sucker is about three times that of the oral. There appears to be a short prepharynx but no esophagus. The intestinal rami extend to the posterior end. Genital aperture median at base of pharynx; cirrus-pouch short, lying at the anterior border of the ventral sucker, and containing the meager prostate and seminal vesicle which is, for the most part, a compactly folded tube. Testes 2, opposite and adjacent, somewhat triangular in outline, and lying near the posterior end. Ovary subglobular, lying between the posterior margin of the ventral sucker and the anterior margin of the right testis; seminal receptacle on right dorsal border of ovary. The vitellaria are diffuse and lie along the posterior and lateral margins, extending to the pharynx. Transverse yolk-ducts lie along the anterior border of the left testis dorsally and on the dorsal side of the ovary; shell-gland dorsal to posterior edge of ventral sucker and along anterior edge of seminal receptacle. The uterus is mainly on the left side between the left testis and the anterior border of the ventral sucker. The metraterm passes on the left of the cirrus-pouch to the genital aperture.

Host, *Calamus calamus:*

1908, June 29, 2 fish, 1 distome; July 11, 5 fish, 1 distome.

Length of first 2.03, breadth 1.54. The latter specimen was yellowish in life. Its dimensions were: Length 2.24, breadth 2.38; oral sucker 0.35; pharynx 0.28; ventral sucker 1.36; ova 0.064 by 0.037.

The dimensions of this specimen in balsam are: Length 2.17; breadth 1.46; neck 0.84; oral sucker, length 0.46, breadth 0.49; pharynx, length 0.42, breadth 0.24; ventral sucker, length 0.70, breadth 0.90; ova 0.061 by 0.034.

Enenterum aureum gen. et sp. nov. (Figs. 66–70.)

Etymology: ἐν, preposition in; ἔντερον, intestine.

Body smooth, nearly linear, tapering near the posterior end and narrowing slightly at the anterior end, dorso-ventrally compressed. Color in life yellow to orange, with transparent or colorless borders at the extremities, particularly the anterior. Mouth surrounded by 10 short rounded lobes arranged in pairs, 2 dorsal, 2 lateral, and 1 ventral, the ventral pair being larger than the others. Oral sucker with its axial diameter greater than the transverse; ventral sucker nearly circular, slightly exceeding the oral sucker, situated at about the anterior fourth. Prepharynx very short, pharynx globular, no esophagus; intestinal rami uniting behind posterior testis near posterior end, the common intestine extending nearly to the posterior end. Genital aperture in front of ventral sucker, a little to left of median line; seminal vesicle, prostate gland, and the short cirrus are included in the space bounded by the anterior edge of the ventral sucker and the rami of the intestines. The vas deferens passes back from the seminal vesicle dorsal to the ventral sucker and a little to the right of the median line. Testes 2, lobed, conspicuous, on middle line one behind the other and near together, the anterior one being about half-way between the ventral sucker and the posterior end. Ovary subglobular, a short distance in front of the anterior testis and a little to the right of the middle line. There is a seminal receptacle which lies dorsal to and extends beyond the caudal border of the ovary. In sections the antero-dorsal part of the ovary was seen to contain large, loosely arranged germ-cells. The shell-gland was dorsal and anterior to this part of the ovary. The vitelline glands are diffuse and extend from a little behind the caudal edge of the ventral sucker to the posterior end, densest along the margins, and scattering over the median region. The folds of the uterus lie between the ovary and the ventral sucker. Metraterm on left of middle line. The excretory vessels are not distinctly shown in the mounted specimens. In the living worms they were seen as lateral vessels behind the ventral sucker, as a median vessel in the posterior third in dorsal view, and again at the posterior end in ventral view.

Host, *Kyphosus sectatrix:*

1906, July 16, 5 fish, 16 distomes.

1908, July 5, 1 fish, 1 distome; July 8, 1 fish, 8 distomes.

Dimensions of living specimen: Length 5; breadth, anterior 0.50, middle 1.12, posterior 1.00; oral sucker 0.42; pharynx 0.28; ventral sucker 0.53; ova 0.058 by 0.032. Length of alcoholic specimens from 3 to 8 mm. The larger specimens, that is those containing ova, are rather thick or cylindrical-compressed, younger specimens are flat.

Theledera (g. n.) pectinata (Linton).

Distomum pectinatum, LINTON, Bull. U. S. Fish Commission, vol. XXIV, p. 389, figs. 200–203.

Etymology: θηλή, nipple; δέρη, neck.

Host, *Auxis thazard:* July 10, 1906, 1 fish, 1 distome.

The only note made at time of collecting was a brief remark referring the single specimen to this species.

The specimen was stained and mounted and found to agree closely with *D. pectinatum*. There is a slight difference in the proportions of the suckers. In this specimen the ventral sucker is rather less than 1.5 times the diameter of the oral, while in the Beaufort forms the ventral sucker is twice or more the diameter of the oral. Dimensions in balsam: Length 1.86; breadth 0.30; neck 0.67; oral sucker 0.14; pharynx, length 0.14, breadth 0.07; ventral sucker 0.18; ova 0.024 by 0.017 and 0.020 by 0.014.

Lepocreadium trulla (Linton). (Figs. 71–74.)

Distomum trulla, LINTON, Proc. U. S. Nat. Mus., vol. XXXIII, p. 109, plate XI, fig. 79.

The distomes here considered agree closely with those found in *Ocyurus chrysurus* in Bermuda.

Body pyriform, truncate at posterior end, triangular in outline when compressed; covered with small, low, rounded spines; oral sucker equal to or slightly exceeding the ventral. The pharynx is separated from the oral sucker by a very short prepharynx, and the esophagus is so short that it is indistinguishable in most of the mounted specimens. The intestines extend to near the posterior end. From a point opposite the caudal border of the ventral sucker to the posterior end the intestinal rami are thick-walled, the columnar cells staining deeply. Testes 2, near posterior end, diagonally placed and near together. Genital aperture median, ventral to bifurcation of the intestine. Cirrus-pouch long-clavate, inclosing the seminal vesicle at its posterior end, which is behind the ventral sucker and close to the anterior edge of the anterior testis; prostate conspicuous in cirrus-pouch from seminal vesicle to near the genital aperture. Ovary 3-lobed, in front of testes, contiguous to anterior edge of anterior testis and a little to the right of the median line. Seminal receptacle in front of anterior testis, to the left of the ovary, and near the caudal end of the cirrus-pouch. Vitelline glands diffuse, abundant, filling the posterior and lateral regions of the body as far forward as the pharynx. Uterus with rather numerous ova between the anterior testis and the ventral sucker; the thick-walled and glandular metraterm lies on the left side of the cirrus-pouch. The excretory vessel is not clearly defined in the mounted specimens, but it was seen as a relatively large, inflated vessel in living specimens, most conspicuous at the posterior end where the opening was surrounded by radiating lines in a definite area (fig. 73).

The spinose cuticle has a tendency to separate rather easily. Many of the mounted specimens show no signs of spines and others have but few. Fresh specimens in good condition are conspicuously spinose.

In 8 out of 12 the oral sucker was larger than the ventral, in the remaining 4 the suckers were equal; even where the oral sucker is the larger the difference is slight. In one the oral sucker measured 0.168 and the ventral 0.154; in another they were 0.158 and 0.144 respectively.

Host, *Ocyurus chrysurus:*

1907, July 10, 3 fish, few distomes; July 12, 3 fish, few distomes.

1908, June 30, 3 fish, 25 distomes; July 1, 1 fish, 12 distomes; July 4, 11 fish, 2 distomes; July 11, 1 fish, 4 distomes; July 14, 1 fish, 2 distomes; July 15, 1 fish, 5 distomes.

Color in life translucent white tinged with yellowish-green.

Dimensions, life, slightly flattened: Length 0.92; breadth, anterior 0.21, near posterior 0.50; oral sucker 0.18; pharynx 0.07; ventral sucker 0.16; ova 0.048 by 0.031.

Host, *Calamus calamus:* July 6, 1907, 1 fish, 1 distome.

Lepocreadium levenseni (Linton). (Figs. 75–77.)

Distomum levenseni, LINTON, Proc. U. S. Nat. Mus., XXXIII, p. 110, plate XII, figs. 80–83.

Certain distomes from Tortugas groupers are here recorded.

One of them, from *Epinephelus striatus*, agrees with *D. levenseni* in every essential particular. The cirrus-pouch is long and passes on the left side of the ventral sucker. It includes the voluminous, tubular seminal vesicle in its basal portion which lies along the median line behind the ventral sucker. The muscular excretory bulb is conspicuous.

Dimensions, life: Length 1.58; breadth, anterior 0.16, middle 0.49, posterior 0.28; oral sucker 0.11; pharynx 0.07; ventral sucker 0.12; ova 0.068 and 0.040. A larger specimen measured 2.75 mm. in length.

Dimensions of a specimen mounted in balsam: Length 1.96; breadth 0.46; neck 0.50; oral sucker, length 0.12, breadth 0.14; pharynx, length 0.07, breadth 0.05; ventral sucker 0.11; ova 0.06 by 0.034.

Three distomes, from *Epinephelus morio* and *Mycteroperca venenosa*, while quite incomplete in that neither cirrus-pouch nor genital aperture could be made out and they may indeed represent different species, are referred to this species provisionally. Thus it is probable that the distome from *Mycteroperca* is specifically different from those found in *Epinephelus*, but on account of the meagerness in the amount of material, and also in view of the fact that there seems to be a considerable range of variation in this species as seen in the material collected from the Bermuda groupers, it would be inadvisable to give to this lot definite specific position at present. In the specimen from *Epinephelus* (fig. 75) the oral sucker was invaginated. The relative size and position of the suckers agree with *D. levenseni*. The pharynx is relatively larger and the vitellaria extend nearly to the bifurcation of the intestine. This latter fact might justify placing them in a different species. There is a distinct esophagus and the thick-walled intestines extend to the posterior end. The relative positions of testes, ovary, seminal receptacle, and uterus agree with the Bermuda specimens. There is a globular, muscular bulb at the excretory pore, as in *D. levenseni*.

In the specimen from *Mycteroperca* (fig. 77) the same resemblances and differences, when referred to *D. levenseni*, prevail as in the specimens from *Epinephelus*. In addition the ventral sucker is situated relatively farther from the anterior end, although in this specimen the oral sucker is not invaginated, so that the neck is not shortened as it is in the specimens from *Epinephelus*. In all the specimens the general outline of the body and the investment of spines are as in *D. levenseni*.

Comparative measurements, specimens in balsam:

[Nos. 1 and 2 from *Epinephelus*, No. 3 from *Mycteroperca*.]

	No. 1.	No. 2.	No. 3.
Length	1.68	2.10	2.45
Breadth	0.56	0.59	0.59
Neck	0.50	0.71	1.03
Oral. sk.	lg. 0.18, br. 0.17	lg. 0.14, br. 0.19	lg. 0.12, br. 0.14
Pharynx	lg. 0.14, br. 0.19	lg. 0.12, br. 0.19	lg. 0.14, br. 0.14
Ventral sk.	lg. 0.15, br. 0.17	lg. 0.14, br. 0.14	lg. 0.13, br. 0.15
Ova	0.061 by 0.037	0.060 by 0.034	0.058 by 0.031

Host, *Epinephelus striatus:* July 7, 1906, 3 fish, 2 distomes.

Host, *Epinephelus morio:* June 29, 1908, 1 fish, 2 distomes.

Host, *Mycteroperca venenosa:* July 16, 1907, 1 fish, 1 distome.

In this specimen small tube-like structures were noted in the walls of the head and neck like those in *Siphodera vinaledwardsii.* Length of this specimen in balsam is 2.28, length of neck, 1.02.

Distomum sp.

Immature, encysted in flesh.

These distomes were encysted in the flesh above the backbone, near the dorsal spines, about midway between the abdominal cavity and base of caudal fin. Diameter of cyst 1.35 mm. There is a general resemblance to the form which I have recorded in reports on the Woods Hole and Beaufort regions under the name *Distomum valdeinflatum* Stoss The worms could be seen plainly through walls of the cysts. Dimensions, flattened: Diameter of anterior sucker 0.20; ventral sucker 0.28; diameter of body, in front of caudal enlargement 0.30, of caudal portion 1.75.

Host, *Calamus calamus:* June 29, 1890, 2 fish were examined and 2 cysts found in one of them.

Mesolecitha linearis gen. et sp. nov. (Figs. 170–172.)

Etymology: *μέσον*, middle; *λέκιθος*. yolk.

The body linear, bluntly rounded at both ends, smooth under low magnification, but when highly magnified minutely or prickly spinose on the margins, cylindrical; mouth subterminal; oral sucker larger than ventral; pharynx adjacent to oral sucker; esophagus short; rami of intestines thick-walled and reaching nearly to the posterior end of the body; ventral sucker at about the anterior fourth. Genital aperture at the anterior border of the ventral sucker; cirrus short, stout, and armed with short spines; prostate conspicuous, dorsal to the ventral sucker and extending beyond its caudal border; seminal vesicle oval, strong-walled, at base of prostate; testes 2, close together, one behind the other and situated a little nearer the ventral sucker than the posterior end. Ovary oval elliptical, a short distance behind the ventral sucker on ventral side of body; shell-gland on right antero-dorsal side of ovary. To the right of the ovary and shell-gland and extending caudad is a convoluted tube, a portion of the uterus, which appears to represent the seminal receptacle with ova lying in the midst of the spermatozoa which fill the tube. Folds of the uterus lie between the testes and the ventral sucker and also fill the body behind the testes to the caudal end. Excretory vessel not made out clearly, but a spacious median vessel was noted extending from the caudal end to the ventral sucker. The ova are characteristically long and slender. The yolk-glands were not conspicuous, the specimens evidently having been producing eggs for a long time. They are diffuse, marginal, and peripheral between the ventral sucker and the anterior testis. Conspicuous nucleated cells form the inner layer of the body-wall from about the level of the middle of the ventral sucker to the posterior end. They are probably yolk-forming cells.

Dimensions of specimen mounted in balsam: Length 4.55; breadth 0.86; oral sucker 0.53; pharynx 0.17; ventral sucker 0.38; ova 0.051 by 0.024 and 0.047 by 0.024 and 0.044 by 0.020.

Host, *Teuthis cæruleus:* July 10, 1908, 1 fish, 2 distomes.

General color orange-yellow. Dimensions of smaller specimen, life, flattened: Length 4.20; breadth 0.90; oral sucker 0.42; pharynx 0.16; ventral sucker 0.23; ova 0.047 by 0.020.

Stephanochasmus casus sp. nov. (Figs. 78–83.)

Body linear to clavate, neck tapering; mouth surrounded by a double row of spines, neck also spinose; all the spines are evanescent; ventral sucker 1.5 to 2 times the diameter of oral sucker; pharynx large, usually pyriform, nearer ventral than oral sucker; prepharynx long, esophagus very short; rami of intestine extend to posterior end of body; genital aperture median at anterior border of ventral sucker; cirrus spinose, cirrus-pouch long, slender, and cylindrical with the seminal vesicle inclosed in its basal portion well behind the ventral sucker and with the prostatic cells in its wall. Testes near posterior end close together, one behind the other, on the median line; posterior testis, in most cases oval and larger than the anterior, which is usually subglobular. Ovary subglobular, at anterior border of anterior testis. There is a seminal receptacle in front of the ovary. The vitelline glands are diffuse and fill the posterior and lateral regions of the body as far forward as the ventral sucker. Out of 9 specimens the vitellaria of 6 extended a little farther on the right than on the left side, reaching as far as the middle of the length of the ventral sucker. The uterus lies between the ovary and the base of the cirrus-pouch. The metraterm is beside and dorsal to the elongated portion of the cirrus-pouch which it joins near the genital aperture. The ova are large, and in the preserved specimens are collapsed in a characteristic manner, with about 6 longitudinal furrows, giving a ribbed appearance to them. In the specimens from *Neomænis griseus* and *Ocyurus* the ova in mounted material were from 0.061 to 0.065 in length. In those from *Neomænis analis* they ranged from 0.075 to 0.085 in length. In those from *Epinephelus* they measured 0.078 in length.

The specimens from *Neomænis analis* were much larger than the others, but they appear to agree with the smaller specimens from the other hosts in all essential particulars. The spines around the mouth and those of the neck were very poorly represented in all the distomes referred to this species.

Dimensions of distomes mounted in balsam.

Host.	Oral sk.	Pharynx.	Vent. sk.	From anterior end to pharynx.	From anterior end to ventral sucker.	Length.	Breadth.
Epinephelus striatus...	lg. 0.11 br. 0.21	0.20 0.16	0.25 0.26	0.44	0.80	2.24	0.50
Neomænis griseus......	lg. 0.14 br. 0.17	0.28 0.17	0.36 0.36	0.52	1.06	2.17	0.72
Do...........	lg. 0.15 br. 0.17	0.24 0.17	0.28 0.30	0.32	0.60	2.35	0.60
Ocyurus chrysurus.....	lg. 0.15 br. 0.18	0.25 0.15	0.28 0.36	0.45	0.70	2.52	0.64
Do...........	lg. 0.17 br. 0.17	0.31 0.21	0.49 0.49	0.60	1.20	4.42	0.77
Neomænis analis.......	lg. 0.28 br. 0.28	0.33 0.22	0.50 0.45	1.37	2.38	5.47	0.77
Do...........	lg. 0.25 br. 0.25	0.31 0.18	0.43 0.42	1.47	2.60	7.00	1.20
Do...........	lg. 0.25 br. 0.25	0.33 0.25	0.50 0.45	1.15	1.90	6.37	0.84

Host, *Neomænis griseus:*

1906, July 5, 11 fish, 3 distomes; July 7, 4 fish, 1 distome; July 9, 14 fish, 3 distomes; July 12, 4 fish, few distomes.

1908, July 14, 4 fish, 1 distome.

Host, *Neomænis analis:* July 1, 1908, 1 fish, 3 distomes.

Host, *Epinephelus striatus:* July 4, 1907, 1 fish, 1 distome.

Host, *Ocyurus chrysurus:*

1906, July 6, 3 fish, 1 distome.

1907, July 11, 3 fish, 1 distome.

1908, July 3, 1 fish, 2 distomes; July 11, 1 fish, 1 distome; July 12, 3 fish, 1 distome; July 14, 1 fish, 1 distome.

One specimen from this host had most of the spines still attached to the circumoral region. There appeared to be 36 in the two circles.

The length of the cirrus spines in a specimen from *Epinephelus*, in life, was 0.01 mm.

Stephanochasmus sentus sp. nov. (Figs. 84–86.)

Body linear or slightly clavate, neck tapering, cylindrical, often arched; mouth surrounded by a double row of spines, 18 in each row; neck and anterior part of the body covered with spines which are evanescent. In some cases the neck was covered with globular tubercles, in others the tubercles were flattened, in still others they were spines of the usual low rounded type. All these conditions appear to be different stages of shedding the spines, which seem to be evanescent, not only those on the neck and body but also those around the mouth. The spines do not, however, appear to be so readily lost as they are in *Stephanochasmus casus.* The oral sucker is variable; the ventral sucker is usually nearly circular in outline and 1.5 times the diameter of the oral sucker; pharynx usually pyriform and much longer than broad, situated near the ventral sucker and separated from the oral sucker by a long prepharynx. There is an esophagus which may be as long as the pharynx, and the intestinal rami extend to the posterior end of the body. Genital aperture median at anterior border of the ventral sucker; seminal vesicle behind ventral sucker inclosed in the posterior end of the cirrus-pouch; prostate gland not conspicuous, represented by cells in the walls of the cirrus-pouch. Testes 2, close together, one following the other in the median line near posterior end. Posterior testis usually long oval, with its long axis corresponding to the long axis of the body; anterior testis smaller, globular or subglobular, or oval; ovary at anterior border of anterior testis, globular or oval. There is a seminal receptacle in front of the ovary. The vitelline glands are diffuse, dense, filling the posterior part of the body and often obscuring the other organs; they extend forward to about the posterior end of the seminal vesicle, thus leaving a considerable area behind the ventral sucker where they do not occur. Folds of the uterus between ovary and base of seminal vesicle; metraterm long, parallel to the slender cirrus-pouch, and uniting with it near the genital opening. The ova are relatively few and large; in preserved specimens they are collapsed in the same manner as in *Stephanochasmus casus*, that is, by the formation of about 6 longitudinal furrows, producing a ribbed appearance. The length of the ova in balsam is about 0.075 mm., though measurements as great as 0.085 mm. were obtained.

Host.	Oral sk.	Pharynx.	Vent. sk.	From anterior end to pharynx.	From anterior end to ventral sucker.	Length.	Breadth.
Calamus calamus.......	lg. 0.10	0.25	0.30	0.52	0.84	3.64	0.55
	br. 0.14	0.14	0.30				
Do...........	lg. 0.11	0.19	0.24	0.35	0.56	1.96	0.42
	br.	0.11	....				
Hæmulon plumieri.....	lg. 0.12	0.11	0.18	0.50	0.70	2.91	0.30
	br. 0.07	0.10	....				
Do...........	lg. 0.11	0.14	0.15	0.50	0.70	2.28	0.38
	br. 0.10	0.07	0.19				
Do...........	lg. 0.08	0.17	0.20	0.46	0.67	2.66	0.30
	br. 0.11	0.10	....				
Hæmulon sciurus......	lg. 0.11	0.18	0.28	0.56	0.84	3.78	0.47
	br. 0.14	0.09	0.22				
Do...........	lg. 0.10	0.14	0.22	0.56	0.77	....	....
	br. 0.12	0.07	0.21				

Host, *Calamus calamus:*

1907, July 10, 2 fish, 9 distomes.

1908, July 7, 1 fish, 1 distome; July 8, 1 fish, 1 distome; July 14, 1 fish, 1 distome.

Host, *Hæmulon plumieri:*

1906, July 8, 1 fish, 2 distomes.

1907, July 1, 4 fish, 1 distome; July 3, 16 fish, 1 distome; July 12, 11 fish, 1 distome.

1908, July 3, 2 fish, 2 distomes; July 6, 5 fish, 1 distome.

Host, *Hæmulon sciurus:* July 2, 1907, 3 fish, 1 distome.

Lechradena edentula gen. et sp. nov. (Fig. 87.)

Etymology: λέχρις, crosswise; ἀδήν, gland.

A single distome evidently near the genus *Stephanochasmus*, but without spines, is here described. It was found in a gray snapper (*Neomænis griseus*), July 5, 1906.

Outline of body very long ovate, broadest near posterior end and tapering rather uniformly to the anterior end; smooth, but neck crossed by fine wrinkles; oral sucker nearly terminal, much smaller than ventral sucker; neck one-third the entire length; prepharynx long, pharynx large. There seems to be a short esophagus, and the wide intestinal branches extend to the posterior end of the body. Reproductive opening on median line at anterior border of ventral sucker; cirrus smooth and cylindrical; cirrus-pouch slender, prostate not seen; seminal vesicle cylindrical, on median line, its anterior end at the caudal border of the ventral sucker; testes 2, near together on median line, one behind the other and contiguous; posterior testis larger and longer than the anterior. Ovary suboval, at anterior border of anterior testis; seminal receptacle in front of ovary a little to right of median line. Vitelline glands diffuse, dense, with a peculiar transverse arrangement of the lobes, from posterior end to ventral sucker. Uterus median, the ova lying between the ovary and the caudal end of the seminal vesicle.

Dimensions in balsam: Length 2.10; breadth 0.61; oral sucker 0.13; pharynx, length 0.18, breadth 0.14; ventral sucker 0.29; ova 0.052 by 0.034.

Mesorchis urna gen. et sp. nov. (Figs. 88–93.)

Etymology: *μέσος*, middle; *ὄρχις*, testicle.

Body variable in shape but usually fusiform, truncate anteriorly, and tapering to a blunt point posteriorly, covered, at least anteriorly, with minute, short spines; oral sucker terminal, vase-shape, broad in front, narrowing at posterior end; ventral border of lip usually rather deeply notched; pharynx close to oral sucker; esophagus long and slender; intestinal rami short, with thick walls, as a rule diverging widely, in which case they do not reach the ventral sucker. The ventral sucker is rather weak and often hard to distinguish in living specimens, its anterior border about the middle of the length of the body. Genital aperture at anterior edge of ventral sucker; cirrus-pouch large, median, vertical; seminal vesicle a large convoluted tube inclosed in the cirrus-pouch and lying dorsal to the ventral sucker. The metraterm passes on dorsal side of ventral sucker, ventral to seminal vesicle. Testes 2, lateral, their anterior borders in front of level of anterior edge of ventral sucker. In what is perhaps an average case a line joining the middle points of the testes passes along the anterior edge of the ventral sucker. Ovary dorsal to ventral sucker, extending a short distance caudad of ventral sucker. At its posterior border is the shell-gland which, in turn, is followed by the seminal receptacle. A short distance back of the seminal receptacle on the dorsal side is the opening of Laurer's canal, which is exceptionally conspicuous. The opening is thick-lipped and surrounded by strongly staining nuclei. The vitelline glands are lateral, mostly in front of the testes, and extending about half-way from the testes to the anterior end. Each lateral gland is composed of a considerable number of compact, rounded, and comparatively small masses. The folds of the uterus are ventral and occupy the greater part of the space behind the testes. The excretory vessel is capacious, with a short, thick stem at the posterior end, soon dividing into two branches which lie ventrally and laterally and extend as far forward as the testes. The shape of the excretory vessel is thus like the letter Y. The ova are pyramidal or ovate, with rather thick shells.

Dimensions in balsam: Length 1.50; breadth, anterior 0.18, middle 0.45, posterior 0.10; neck 0.70; oral sucker, length 0.21, breadth 0.18; pharynx, length 0.08, breadth 0.06; ventral sucker 0.16; ova 0.031 by 0.019.

Host, *Angelichthys isabelita:*
1906, July 10, 1 fish, 1 distome.
1908, July 3, 1 fish, 3 distomes.
Host, *Pomacanthus arcuatus:*
1906, July 18, 1 fish, 5 distomes.
1907, July 3, 1 fish, 12 distomes; July 11, 1 fish, 238 distomes; July 15, 1 fish, 150 distomes.
1908, June 29, 1 fish, 93 distomes; July 1, 1 fish, 39 distomes; July 3, 2 fish, 68 distomes; July 4, 2 fish, 28 distomes; July 5, 2 fish, 2 distomes; July 7, 2 fish, 6 distomes.

The color of these distomes in life in some cases was red. The shape varied from long oval to short oval. Measurements of ova showed a variation in the same individual of 0.037 by 0.017 and 0.031 by 0.019. The length in one of the smaller lots varied from 0.84 to 1.68.

Diplangus paxillus gen. et sp. nov. (Figs. 94–101.)

Etymology: διπλόος, double; ἄγγος, vessel.

This distome is characterized by its cylindrical body, which is attenuate posteriorly, and by its prominent ventral sucker. Although found on many occasions, my material does not allow details of structure to be made out with entire satisfaction.

Body cylindrical, smooth, thickest at ventral sucker, neck abruptly conical, body usually attenuate behind ventral sucker and tapering to the posterior end. Oral sucker subterminal; pharynx adjacent to oral sucker or separated from it by a very short prepharynx; ventral sucker larger than oral, prominent, almost pedicelled in some; esophagus short; intestinal rami extending a little more than half-way to the posterior end. Genital aperture median, ventral to pharynx; cirrus short, slender; seminal vesicle in two parts, a posterior prostatic portion with large cells in the wall and an anterior globular portion with thinner walls (*sv* and *pr* in figs. 94–100). The testes are 2, globular, near together, one behind the other, and placed about half-way between the ventral sucker and the posterior end. Ovary dorsal, a short distance in front of testes; seminal receptacle immediately in front of ovary. The vitelline glands are clustered lateral masses behind the ventral sucker and extending to the ovary. The folds of the ovary fill the body both in front of and behind the testes; ova oblong-elliptical, the long diameter twice the shorter. Numerous glandular cells in the neck are interpreted to be yolk-forming.

Host, *Hæmulon macrostomum:*
1907, June 28, 2 fish, 1 distome.

Dimensions, life, flattened: Length 1.35; breadth 0.40; oral sucker 0.14; pharynx 0.11; ventral sucker 0.21; ova 0.036 by 0.017.

1907, July 12, 1 distome, length 1.75.

Host, *Hæmulon plumieri:* July 13, 1906, 2 fish, 1 distome.

Dimensions, life: Length 1.75; breadth, anterior 0.16, base of neck 0.50, middle 0.40, posterior 0.21; oral sucker 0.14; pharynx 0.07; ventral sucker 0.20; ova 0.037 by 0.020. Body filled with minute ovate bodies, 0.003 in length, not seen in the mounted specimen.

1906, July 8, 1 fish, 1 distome; July 15, 1 fish, 1 distome.

1907, June 27, 2 fish, 1 distome; July 6, 16 fish, 6 distomes; July 8, 2 distomes; July 10, few distomes; July 12, few distomes; July 13, 1 distome.

1908, July 3, 2 fish, 1 distome; July 6, 5 fish, 1 distome; July 9, 1 fish, 2 distomes; July 10, 5 fish, 1 distome; July 11, 2 fish, 1 distome; July 12, 1 fish, 1 distome; July 14, 14 fish, few distomes.

Host, *Hæmulon sciurus:*

1907, June 28, 1 fish, 1 distome.

1908, July 2, 1 fish, 1 distome.

Dimensions, life: Length 1.20; breadth 0.25; oral sucker 0.08; ventral sucker 0.15; ova 0.030 by 0.015.

Host, *Calamus calamus:*

1907, July 6, 1 fish, 1 distome; July 10, 2 fish, 1 distome.

Dimensions, life, flattened: Length 1.47; breadth 0.53; oral sucker 0.13; pharynx 0.08; ventral sucker 0.21; ova 0.041 by 0.017. Scattered among the ova and also in other parts of the body were immense numbers of small oval bodies, 0.007 by 0.004. These are not evident in the mounted specimen.

Deretrema fusillus gen. et sp. nov. (Figs. 102–104a.)

Etymology: *δέρη*, neck; *τρῆμα*, hole.

The description which follows is based on a distome from *Ocyurus chrysurus* (fig. 102). Other distomes from *Hæmulon macrostomum* and *Abudefduf saxatilis* are referred to the same species with some hesitation.

Body smooth, in living specimen crossed by minute, transverse, wavy lines, close together and occasionally reticulated. Color in life translucent yellow, deeper amber near center when slightly flattened, ventral sucker with reddish granular pigment, ovary pink by transmitted, white by reflected, light. The shape is fusiform, the greatest thickness being at the middle through the ventral sucker, tapering to a bluntly rounded point at the anterior end and to a sharper point at the posterior end. The oral and ventral suckers are each nearly circular in outline, the ventral being more than 1.5 times the diameter of the oral. Pharynx adjacent to oral sucker, broader than long; esophagus broad and thin-walled; intestines almost entirely concealed by the uterus. Reproductive aperture on left side at about level of the bifurcation of the intestine; cirrus short; cirrus-pouch incloses the seminal vesicle, which is oval and lies transverse to the axis of the body. No prostate was seen, but a few cells around the cirrus probably represent that organ. Testes 2, lateral, opposite, a short distance back of the ventral sucker. They are rather small and long oval, and are near the lateral margins of the body. The ovary is an oval body dorsal to the right caudal margin of the ventral sucker. At its left side is a globular, rather strong-walled sac, in the mounted specimen very slightly stained and empty, which seems to be the seminal receptacle. The vitelline glands are compact, subglobular bodies, about 6 or 8 visible on each margin without deep focussing. They lie on each margin lateral to the ventral sucker, the cluster on the right occupying a little less, and the cluster on the left a little more, than the diameter of the ventral sucker. The uterus is very voluminous and fills almost all of the postacetabular region, its folds being very numerous and distinct in the living specimen. A considerable mass of ova lies in front of the ventral sucker. The eggs are small and there seems to be some variety in the size. The excretory vessels were conspicuous in the living worm and are still more easily seen than usual in the mounted specimen. Inflated vessels are to be seen on each side of the esophagus, and a longitudinally ribbed posterior vessel, though less easily seen than in the living worm. The length in life was 2.10 and the breadth 0.90, and the ova 0.034 by 0.020.

Dimensions in balsam: Length 1.82; breadth 0.64; neck 0.66; oral sucker 0.25; pharynx, length 0.07, breadth 0.08; ventral sucker 0.43; ova largest 0.037 by 0.024, smallest 0.027 by 0.015.

Host, *Ocyurus chrysurus:* July 15, 1908, 1 fish, 1 distome.

Two distomes from *Hæmulon macrostomum* are referred to this species with much hesitation, not only with regard to placing them in this species, but as to whether they themselves should be placed in the same species.

These distomes are figured (figs. 103, 104) and may be seen to be quite different in shape. The differences, however, do not appear to me to be sufficient to justify their separation at present. The esophagus and intestine in fig. 104 were very indistinct, and the apparent shortness of the esophagus may be due to the contracted condition of the neck. The metraterm lay on the anterior border of the cirrus-pouch instead of on its caudal border, as in the specimen figured in figs. 102 and 104. Since all the specimens were more or less flattened and consequently somewhat distorted, the difference may be due to forced displacement.

Dimensions of the specimen shown in fig. 103, mounted in balsam: Length 1.68; breadth 0.58; neck 0.72; oral sucker 0.21; pharynx, length 0.06, breadth 0.08; ventral sucker, length 0.35, breadth 0.32; ova, largest 0.044 by 0.024, smallest 0.034 by 0.024, usual size about 0.040 by 0.020.

Host, *Hæmulon macrostomum:* July 10, 1906, 2 distomes.

A distome found in the cow pilot (*Abudefduf saxatilis*), July 15, 1906, appears to belong here.

The stained and mounted specimen is little more than a mass of ova. The following features, however, can be recognized: The testes are 2, nearly opposite each other at about the posterior third, each near the lateral margin of its side. The ovary is near the middle line, a short distance in front of the testes. The vitelline glands consist of a few granular masses along the margins extending from about the level of the ovary for a short distance toward the anterior end. The anterior end is probably broken.

Dimensions: Length 1.40; breadth, anterior 0.42, middle 0.60; maximum breadth about posterior fourth 0.72; ova 0.040 by 0.017.

Distomum fenestratum Linton. (Figs. 105, 106.)

These distomes were active, the neck, when fully extended, being quite slender and as long as that part of the body which lay behind the ventral sucker. When the neck was thus stretched out it was seen that the convoluted tubule shown in sections (Proc. U. S. N. M., vol. XXXIII, plate XIII, fig. 90) and in contorted specimen (Bull. U. S. Fish Commission, vol. XXXIV, plate XXX, figs. 213, 214) is really made up of the caudal end of the esophagus and the beginnings of the intestinal rami.

These specimens agree closely with the forms which I have described from *Coryphæna* at Beaufort and *Lycodontis* at Bermuda. Measurements were not made at the time of collecting and the only specimen which I have preserved is broken. The length, estimated, is 3.5 and the breadth 0.40. Sections show the parenchyma to be reticulated. The body-wall is lined with glands whose exact nature is not evident. They strongly resemble the cells which I have interpreted as yolk-forming cells in other distomes described in this paper. These cells begin on the dorsal side in front of the ventral sucker. Behind the ventral sucker they surround the body cavity to the posterior end. The diameter of the oral sucker in the specimen sectioned is 0.08, of ventral sucker 0.19.

Host, *Hæmulon plumieri:*

1908, June 28, 2 fish, 1 distome; July 4, 12 fish, 1 distome.

Host, *H. sciurus:*

1907, July 1, 1 fish, 2 distomes.

Length of one in life 2.10, breadth 0.42. There was a rudiment of a slender organ in front of the ventral sucker.

XYSTRETRUM gen. nov.

Etymology: *ξύστρα*, scraper, rasp; *ἦτρον*, belly.

Generic characters: Neck cylindrical; body suborbicular with a thin border and thickened central portion, which is crossed on its ventral surface by numerous, low, transverse ridges. Testes nearly opposite, behind ventral sucker; ovary in front of testes; vitelline glands median behind ventral sucker and in front of testes; folds of uterus mainly behind testes; genital aperture median, behind oral sucker; pharynx none.

The posterior ends of the intestinal rami approximate, but whether they actually unite could not be ascertained.

Xystretrum solidum gen. et sp. nov.

Distomum sp., Proc. U. S. Nat. Mus., vol. XXXVI, p. 119, plate XV, figs. 100-102.

The most obvious difference between this and the following species is the more compact character of the vitelline glands and the tendency of the border to roll under in the Bermuda species.

The longitudinal striæ on the ventral disc are simply the longitudinal muscle fibers of the body-wall. These striæ are 0.02 mm. apart.

Xystretrum papillosum gen. et sp. nov. (Figs. 107–111.)

Neck distinct from body, cylindrical, arcuate; body suborbicular with thin border and thickened, muscular ventral disc crossed by low, transverse ridges. Papillar spines cover the neck and body and line the cavities of the suckers. In life, color of neck pink, of body yellow with white margin; mouth subterminal; ventral sucker larger than oral; no pharynx, no esophagus; intestinal rami in the neck with irregular outline extending to posterior edge of disk. The intestines follow the lateral borders of the disk but being obscured by the uterus it could not be determined whether they unite at the posterior end or not. Genital aperture median, ventral, near the posterior border of the oral sucker; cirrus short and smooth; cirrus-pouch between the intestinal rami in front of the ventral sucker, inclosing the convoluted seminal vesicle; prostate not distinct. Testes 2, nearly transverse, deeply lobed, situated a short distance behind the ventral sucker. Ovary indistinctly lobed, close to anterior border of right testis. Vitelline glands between the left testis and ovary at caudal border of ventral sucker, made up of about 4 very irregular and somewhat lobed tubular masses. The uterus is a very slender tube lying in intricate folds and filling all the body behind and lateral to the testes except the thin border which lies outside the ventral disk. The metraterm lies on the right side of the seminal vesicle and appears to enter the cirrus to open with it by a common duct; ova small and presenting some variety in size.

Dimensions in balsam: Neck, length 1.40, breadth at anterior end 0.50, at base 0.73; body, length 2.10, breadth 2.17; oral sucker, length 0.42, breadth 0.45; ventral sucker, length 0.62, breadth 0.63; diameter of ventral disc 1.58; distance between ridges of disk 0.04; ova 0.030 by 0.015 and 0.040 by 0.020.

Host, *Lactophrys triqueter:* July 8, 1908, 1 fish, 1 distome.

Hysterolecitha rosea gen. et sp. nov. (Figs. 112–117.)

Etymology: ὕστερος, last, posterior; λέκιθος, yolk.

Body smooth, cylindrical, red in life, greatest diameter at ventral sucker, which is situated near the anterior third of the length, thence tapering to each end; mouth subterminal, oral sucker and pharynx each nearly globular and contiguous; ventral sucker nearly three times the diameter of oral sucker; esophagus about as long as the pharynx. The intestinal rami extend nearly to the posterior end. Reproductive aperture on the midventral line at the junction of the intestinal rami. Cirrus short; prostate represented apparently only by a small cluster of cells near the reproductive aperture. The seminal vesicle is an elongated tube, somewhat convoluted and lying beside the metraterm in the neck. Testes 2, near together, one following the other a little diagonally, not far back of the caudal border of the ventral sucker. The ovary is situated towards the posterior end, at about the posterior fourth or fifth, subglobular; yolk-glands at caudal border of ovary, 2, the left deeply lobed, the right less deeply lobed. There is a seminal receptacle which is tubular and situated behind the yolk-glands. The shell-gland is dorsal to the yolk-gland and there is a yolk-reservoir on the dorsal side of the ovary. The folds of the uterus are most abundant between the ovary and testes, although the uterus begins at the caudal border of the yolk-glands and the folds extend to the ventral sucker, whence the metraterm traverses the neck to the reproductive aperture. The excretory vessel is slightly enlarged at the posterior end near the excretory pore. It is a single ventral vessel thence to a point about on a level with the anterior testis, where it divides, the two branches passing forwards laterally to unite above the pharynx. Length 2 to 5.5 mm.

Host, *Teuthis hepatus:*

1907, July 1, 1 fish, 12 distomes.

Two of the distomes from this host, collected on this date, were apparently macerated. The reproductive organs were mere vestiges. The bodies were filled with ova associated with black pigment. Bodies cylindrical, neck short. While the details of structure are too meager to permit of identification the distomes are probably near this species.

Dimensions of larger, life: Length 5; oral sucker 0.22; pharynx 0.14; ventral sucker 0.50; ova 0.027 by 0.015.

1908, July 11, 1 fish, 3 distomes; July 11, 3 fish, 3 distomes; July 14, 3 fish, 7 distomes; July 15, 1 fish, 3 distomes.

Bright red by reflected, yellow by transmitted light; irregular cylindrical, more or less contorted.

Dimensions, life, flattened: Length 4.5; breadth 0.73; oral sucker 0.23; pharynx 0.10; length of ventral sucker 0.70; ova 0.027 by 0.017. The surface of some specimens was nodular, especially on the neck.

Host, *Teuthis cæruleus:*

1908, June 27, 1 fish, 2 distomes; July 5, 1 fish, 1 distome; July 10, 1 fish, 1 distome.

Pale red, intestines black.

Dimensions, life, flattened: Length 5.5; breadth, anterior 0.32, at ventral sucker 0.92, behind ventral sucker 0.65, posterior 0.28; oral sucker 0.28; pharynx 0.15; ventral sucker 0.77; ova 0.030 by 0.015.

Macradena perfecta gen. et sp. nov. (Figs. 118, 119.)

Etymology: μακρός, long; ἀδήν, gland.

The following notes are based on a series of longitudinal horizontal sections, and a few transverse sections, the greater part of the transverse series having been lost by accident.

Body crossed by fine rugæ, linear, tapering very slightly at the extremities; neck between one-fifth and one-sixth the entire length; mouth ventral; esophagus very short; reproductive aperture about on a level with caudal end of pharynx; cirrus-pouch long, cirrus short, prostatic portion long and slender, extending 0.3 mm. caudad of the ventral sucker. The seminal vesicle is at the caudal end of the prostate and beside the anterior testis. The testes are ovate, their longer axes transverse to the long axis of the body. They lie close together one behind the other. The ovary, which in some of these sections appears to be 2-lobed, is near the caudal border of posterior testis. The outline of the section of the ovary shows the organ to be long oval, with its longer axis transverse. Behind the ovary and contiguous with it is the relatively large seminal receptacle, and ventrally on the right side of the ovary are the lobes of the yolk-gland. This organ is deeply lobed, the lobes being long clavate and apparently radiating from the right side. The ova are very numerous, the entire body back of the ventral sucker being in large part filled with them. They lie in dense masses behind the seminal receptacle and between the ventral sucker and the ovary. The excretory vessels could not be made out satisfactorily in the sections.

Host, *Teuthis cœruleus:* June 27, 1908, 2 distomes.

These were associated with the species of *Hysterolecitha rosea* and were not noted until after they had been sectioned.

Dimensions: Length 2.55; breadth 0.45; oral sucker, length 0.28, breadth 0.22; pharynx, length 0.13, breadth 0.11; ventral sucker, length 0.32, breadth 0.28; ova 0.024 by 0.014.

Opisthadena dimidia gen. et sp. nov. (Figs. 120–122.)

Etymology: *ὀπίσθιος*, hinder; *ἀδήν*, gland.

Body rather slender, linear, compressed; ventral sucker three or more times the diameter of the oral; neck very short and conical; pharynx subglobular adjacent to the oral sucker; esophagus very short, only recognized in sections; intestinal rami extend to the posterior end. Genital aperture between oral and ventral sucker on median line; cirrus short and smooth; prostate large, elongated, along median line, dorsal, behind ventral sucker, extending nearly to the middle of the length of the body and followed closely by the seminal vesicle. Testes 2, one behind the other and behind the middle of the body, oval, transverse. Ovary situated a short distance behind the posterior testis, ovate, the longer diameter transverse; yolk-glands 2, lying side by side immediately behind the ovary; seminal receptacle dorsal to the ovary; shell-gland behind the ovary and between the yolk-glands. The uterus begins behind the yolk-glands where a few folds lie; folds of the uterus in mature specimens occupy the middle region of the body forward to the posterior border of the ventral sucker, few between ovary and testis and between the testes, but abundant in front of the testes. Anteriorly the metraterm passes beside the prostate dorsal to the ventral sucker. It appears to join the male genital duct a short distance from the genital aperture. The ova are a little more than twice as long as broad. The excretory vessel is single from the posterior end to a point a short distance behind the ventral sucker. It there divides and the two lateral branches unite above the oral sucker.

A characteristic of this species is the very coarse muscle fibers which lie in the body-wall. Coarse, longitudinal fibers also occur in the intestinal walls. These intestinal muscles make their appearance near the caudal border of the ventral sucker and continue to the posterior end. They are strongest in the middle regions and grow somewhat weaker toward the posterior end.

The first specimen collected was young. The intestines in the middle third of the body were inflated, and there were two distinct lateral papillæ situated one on each side of the body opposite the antero-lateral border of the ventral sucker (fig. 120). This character was noted in subsequent finds, although it did not always present quite the same appearance shown by the one sketched.

The living worms are characteristically colored, the testes and ovary being ivory-white, the intestine and vitellaria golden-brown.

Length of alcoholic specimens 3.5 to 7 mm.

Dimensions of living specimen (fig. 120): Length 2.80; breadth at ventral sucker 0.45, behind ventral sucker 0.42; oral sucker 0.14; pharynx 0.07; ventral sucker 0.40.

Ova, balsam: 0.038 by 0.014 and 0.042 by 0.017.

Host, *Kyphosus sectatrix:*

1907, July 16, 5 fish, 1 distome.

1908, July 5, 1 fish, 6 distomes; July 8, 1 fish, 9 distomes.

Brachadena pyriformis gen. et sp. nov. (Figs. 123–126.)

Etymology: βραχύς, short; ἀδήν, gland.

Body fusiform, greatest breadth at level of ventral sucker, in most cases tapering to each end. In some the posterior end is bluntly rounded. Oral sucker subterminal, about one-third the diameter of the ventral sucker; pharynx contiguous with the oral sucker; no esophagus; intestines extend to the posterior end. Reproductive aperture ventral to pharynx; cirrus and the relatively large prostate between the oral and ventral suckers; seminal vesicle at caudal border of prostate, usually partly dorsal to the ventral sucker. Testes 2, transversely placed, at caudo-lateral margin of ventral sucker; ovary subglobular, behind testes on median line; seminal receptacle dorsal and extending a little beyond the right anterior border of the ovary. The yolk-glands are about 7 long-pyriform lobes radiating from the caudo-lateral border of the ovary; uterus filling the body generally behind the ventral sucker to the posterior end and dorsal to and on right side of ventral sucker.

A few small distomes (fig. 124) are also referred to this species. They may belong to another species, but my material does not justify a more complete separation than is involved in this special mention.

Host, *Hæmulon macrostomum:* 1906, July 13, 1 fish, 1 distome.

Dimensions, life: Length 1.12; breadth, anterior 0.19, middle 0.70, posterior 0.42; pharynx 0.07; ventral sucker 0.50; ova 0.034 by 0.017 and 0.040 by 0.020.

Host, *Hæmulon plumieri:*

1906, July 8, 1 fish, 1 distome; July 10, 24 fish, 6 distomes.

1907, July 3, 16 fish, 1 distome; July 13, 6 fish, few distomes.

Dimensions, life: Length 1.26; breadth, anterior 0.14, middle 0.70, posterior 0.28; oral sucker, length 0.08, breadth 0.16; pharynx, length 0.05, breadth 0.08; ventral sucker 0.53; ova 0.040 by 0.020. In this specimen the oral sucker and pharynx were variable.

Host, *Hæmulon sciurus:*

1907, June 28, 1 fish, 1 distome; July 1, 1 fish, 1 distome.

Dimensions, balsam: Length 0.65; breadth 0.43; oral sucker 0.11; pharynx 0.04; ventral sucker 0.33; ova 0.034 by 0.017. This specimen is shown in fig. 124.

1907, July 5, 6 fish, 1 distome.

1908, July 7, 1 fish, 1 distome.

Dimensions, life: Length 1.82; breadth 0.98; oral sucker 0.15; pharynx 0.07; ventral sucker 0.49; ova 0.037 by 0.020.

Host, *Calamus calamus:* July 10, 1907, 2 fish, 1 distome.

Dimensions: Length 0.84; breadth 0.42; oral sucker 0.12; pharynx 0.05; ventral sucker 0.28; ova 0.031 by 0.017.

Dichadena acuta gen. et sp. nov. (Fig. 127.)

Etymology: *δίχα*, in two; *ἀδήν*, gland.

Body smooth, fusiform but tapering more toward anterior than posterior end, greatest breadth back of ventral sucker; neck conical, its length but little exceeding the diameter of the ventral sucker; oral sucker subventral, its diameter scarcely equal to one-third the ventral sucker; pharynx short-pyriform adjacent to oral sucker; esophagus apparently none; intestinal rami obscured by the enormous number of ova but probably extending to, or nearly to, the posterior end. Genital aperture on median line about half-way between the suckers; cirrus short; cirrus-pouch oval and containing numerous cells. From this oval pouch a long prostatic tube passes diagonally to the left margin, extending farther caudad than the posterior margin of the ventral sucker. The prostatic tube is clavate, increasing in size gradually to the posterior end, and the prostatic cells are confined to the posterior half of the tube. At the caudal end of the prostate there is an oval seminal vesicle which is sharply marked off from the prostate. A short vas deferens leads back from the seminal vesicle to the testes, which are two in number, one following the other and contiguous to each other. They lie near the left margin and about half-way between the ventral sucker and the posterior end. The ovary lies on the median border of the posterior testis. It is oval and its longer diameter is transverse. The shell-gland is on the dorsal side of the ovary, in ventral view appearing on its left border (fig. 127 *sg*). The seminal receptacle is relatively large, oval, and lies on the caudal borders of the ovary and the posterior testis. The vitelline gland is on the antero-lateral border of the ovary and consists of 6 or more rounded lobes somewhat indistinctly divided into two main masses. A cluster of nucleated cells lies in front of the vitelline glands between them and the ventral sucker, and a large number of similar cells fill the neck. These I take to be yolk-forming cells. The ova are abundant and fill all the posterior parts of the body not occupied by the other organs from the ventral sucker to the posterior end.

Host, *Teuthis cæruleus:* July 6, 1908, 1 fish, 2 distomes.

Dimensions, life: Length 1.89; breadth 0.53; oral sucker 0.08; pharynx 0.04; ventral sucker 0.32; ova 0.024 by 0.015.

Dimensions in balsam: Length 1.55; breadth 0.58; neck 0.38; oral sucker 0.08; pharynx 0.05; ventral sucker, length 0.28, breadth 0.31; ova 0.024 by 0.014.

In the other specimen the ventral sucker measures 0.35 in length and 0.29 in breadth.

Leurodera decora gen. et sp. nov. (Figs. 128, 129.)

Etymology: λευρὸς, smooth; δέρη, neck.

Body smooth, compressed, long ovate, greatest breadth back of ventral sucker; middle of ventral sucker about middle of length of body, or a little nearer posterior than anterior end; diameter of oral sucker about half that of ventral; oral sucker ventral; pharynx a little longer than broad, adjacent to the oral sucker; esophagus short or none; intestinal rami, often inflated, extend to posterior end of body. Genital aperture ventral, on median line just behind pharynx; cirrus short, prostatic cells few, small; cirrus-pouch about dorsal to bifurcation of intestine; seminal vesicle dorsal, median, extending from cirrus-pouch to ventral sucker; metraterm ventral to seminal vesicle. Testes 2, lateral, opposite, behind ventral sucker; ovary median, behind testes; seminal receptacle in front of ovary at its anterior border; vitelline glands 2, slightly lobed, situated to right of ovary and behind the right testis. The folds of the uterus occupy a large part of the body in front of the ventral sucker and behind it, between the testes and behind the ovary, in some cases largely obscuring the other organs. The excretory vessel is single, median, and dorsal to ovary, from posterior end to a point a short distance behind the ventral sucker, where it divides into two branches. The two anterior branches meet above the anterior end of the pharynx. The posterior stem was seen in one case to be deflected to the left. Ova small, about twice as long as broad.

Host, *Hæmulon macrostomum:*

1906, July 10, 1 fish, 2 distomes; July 13, number not noted, few.

1907, June 28, 2 fish, 2 distomes; July 13, 1 fish, 6 distomes.

Dimensions, life: Length 2.24; breadth 0.73; oral sucker 0.22; pharynx 0.08; ventral sucker 0.39; ova 0.04 by 0.02.

Host, *Hæmulon plumieri:*

1907, July 15, 1 fish, distomes few.

1908, July 6, 1 fish, 1 distome.

Dimensions, balsam: Length 1.96; breadth 0.68; oral sucker 0.22; pharynx 0.11; ventral sucker 0.40; ova 0.039 by 0.017.

Host, *Hæmulon sciurus:*

1907, June 28, 1 fish, few distomes.

Dimensions in life: Length 1.50; breadth 0.68; oral sucker 0.22; pharynx 0.13; ventral sucker 0.51; ova 0.038 by 0.018.

Host, *Anisotremus virginicus:* July 6, 1907, 1 fish, 1 distome.

Dimensions, life: Length 1.89; breadth 0.74; oral sucker 0.22; pharynx 0.12; ventral sucker 0.45; ova 0.037 by 0.017.

Host, *Neomænis griseus:*

One specimen found on a slide containing distomes from this host. Length 0.91; breadth 0.47.

Host, *Teuthis hepatus:*

1908, July 11, 1 fish, 1 distome.

Dimensions, life: Length 0.86; breadth 0.44; oral sucker 0.22; pharynx 0.09; ventral sucker 0.29; ova 0.031 by 0.017.

Dictysarca virens gen. et sp. nov. (Figs. 130–136.)

Etymology: δίκτυον, network; σάρξ, flesh.

Body variable, pyriform, fusiform, or ovate when at rest, rather thick, translucent greenish. So far as observed the body appears to be characteristically reticulated, especially when viewed with transmitted light; ventral sucker 1.33 to 1.5 times the diameter of the oral; neck approximately 0.25 the entire length; pharynx adjacent to oral sucker; esophagus short or none; intestinal rami, inflated in some cases, extend to the posterior end. Genital aperture median, ventral, a short distance behind mouth; cirrus very short, prostatic portion vertical, cells small, tube relatively large, continuing in a seminal vesicle dorsal to the ventral sucker. Testes 2, lateral, opposite, a short distance back of the ventral sucker, ovary towards the posterior end, dorsal; shell-gland and seminal receptacle ventral to ovary; vitelline glands 2, lobed, in front of ovary. Folds of the uterus voluminous, mainly dorsal, from near the posterior border of the ventral sucker to near the posterior end; ova small. The metraterm is ventral to the seminal vesicle, turns sharply ventrad just behind the prostate, and runs parallel to the caudal border of the prostate to open with it into the common genital duct.

The excretory vessels appear to unite above the oral sucker. They approach each other a short distance back of the ventral sucker. At first they are ventral to the intestines, behind the ventral sucker they become median, later they are variable. Thus in the vicinity of the yolk-glands the intestinal rami are close together and the excretory vessels are lateral to them. Near the posterior end they unite into a single larger vessel which opens at the posterior end. The excretory pore is surrounded by numerous nucleated cells.

In sections the intestines are seen to be about midway in a dorsoventral direction. The yolk-glands are ventral and nearly symmetrically placed on either side of the median line. The shell-gland is between them and about on the same level. On the right margin, at about the posterior third and for some distance back, the folds of the uterus contain copious spermatozoa mingled with the ova. In all of my specimens the parenchyma is characteristically areolar, as shown in figs. 133 and 134. Among the specimens which I have studied there are individuals in which only rudiments of the genital organs appear. In them as well as in the larger specimens there is the same loose, areolar structure of the parenchyma. There is, however, a larger proportion of structureless material in the loose framework of tissue in the smaller specimens than in the larger. One of the small distomes when sectioned showed rudiments of an ovary, but little more that could be distinguished with certainty.

Dimensions of 3 specimens in balsam, each more or less compressed.

	From L. moringa.		From L. funebris.
Length	3.64	3.90	4.27
Breadth	1.05	1.61	1.54
Neck	0.91	0.89	1.07
Oral sucker	0.22	0.28	0.42
Pharynx	0.11	0.11	0.22
Ventral sucker	0.33	0.39	0.54

Average dimensions of ova, alcoholic: 0.03 by 0.02.

Host, *Lycodontis moringa:* July 2, 1907, 1 fish, 4 distomes.

Dimensions: Length of largest 5 mm., breadth 2.5 mm. Intestine in one filled with dark-brown or black granular material. Suckers filled with blood-cells of host.

Host, *Lycodontis funebris:*

1906, July 4, 1 fish, 4 distomes from swim-bladder; June 28, 2 fish, 4 distomes from swim-bladder.

1908, July 7, 1 fish, 2 distomes from swim-bladder.

The following remarks are condensed from notes made at the time of collecting the material from *L. funebris.*

In the first lot the genitalia were not well developed. One of the specimens was 2.5 mm. in length, 1.75 in breadth, and 1.25 in thickness. After it had been flattened and fixed over the flame it measured 5 mm. in length and 2 in breadth. In the second lot two distomes were found in the swim-bladder of each of the morays. The largest was 5 mm. in length and 3 in breadth. Uterus voluminous, yellow; intestines dark brown; other organs white or colorless. In the third lot the distomes were variable, tense, body-wall thin. One of them burst open after lying for a short time in sea-water. The other at times contracted into a nearly spherical shape, and then changed to pyriform, short-clavate, cylindrical, arcuate. The prevailing color white, uterus in voluminous folds on dorsal side, golden-yellow, other genitalia ivory-white; intestine dark brown; dark-brown, irregular lines showing through the body-wall throughout the entire length appear to be excretory vessels. The uninjured specimen was killed in 70 per cent alcohol and straightened with a brush. It then measured 10 mm. in length and 5 in breadth.

Theletrum fustiforme gen. et sp. nov. (Fig. 137.)

Etymology: *θηλή*, nipple; *ἦτρον*, the belly.

The following description is based on a single specimen mounted in balsam and seen in lateral view.

Body cylindrical with rather thick walls, enlarging slightly to posterior end; smooth, but somewhat corrugate with transverse striæ and with a cluster of low but distinct rounded papillæ on the ventral surface behind the ventral sucker and occupying a little less than the middle third of the length; neck equal to about one-fourth the length. Oral sucker subterminal, approximately half the diameter of the ventral sucker; pharynx subglobular, contiguous with the oral sucker; esophagus two or more times as long as the pharynx. The intestinal rami are slender, slightly sinuate, and extend to the posterior end. Genital aperture immediately behind pharynx, ventral, median; cirrus-pouch pyriform with conspicuous prostate and muscular cirrus; seminal vesicle a conspicuous and convoluted tube lying to the left and behind the cirrus-pouch; cirrus-pouch and seminal vesicle lying in neck. Testes 2, rather small, somewhat pyriform, nearly opposite, and nearly at the middle point of the length of the body. Ovary long-oval, near the posterior end of the body, with the shell-gland at its caudal border; vitelline glands 2, subglobular, behind the ovary and touching each other, the more anterior one in contact with the ovary. A fold of the uterus lies behind the vitelline glands, and other folds fill the space not occupied by the other organs between the ovary and the ventral sucker. A muscular seminal receptacle, pyriform in shape and about the size of a testis, lies a short distance behind the testes. The metraterm passes ventrad of the seminal vesicle and cirrus-pouch and opens at the genital aperture. The ova are small and very numerous.

Dimensions of the specimen mounted in balsam: Length 1.47; breadth, near anterior end 0.18, at ventral sucker 0.22, near posterior end 0.35; length of neck 0.36; oral sucker, length 0.08, breadth 0.04; pharynx 0.03; ventral sucker 0.18; ova 0.024 by 0.013.

Host, *Pomacanthus arcuatus:* July 18, 1906, 1 fish examined, 1 distome.

This distome was not studied much at the time of collecting. The following measurements were made on the living worm: Length 1.82; breadth, anterior 0.21, middle 0.32, posterior 0.35; oral sucker 0.09; ventral sucker 0.22; ova 0.025 by 0.014.

Hemiurus merus sp. nov. (Fig. 138.)

The distomes which are referred to this species agree so closely with the species which I have recorded under the name *Distomum appendiculatum* (Bull. U. S. Fish Commission for 1899, p. 289, plate 36, figs. 25, 26) that I was at first disposed to refer them to that species. When they are compared with specimens in my collection from the alewife they are seen to be specifically different. Although the character of the seminal vesicle in this species is different from that required for the genus *Hemiurus*, I place it in that genus, preferring to extend the limits of the genus rather than to be a party to any further dismemberment of the genus.

The following description is based on specimens which were stained and mounted in balsam.

Body cylindrical to fusiform and clavate, crossed by striæ which make a sharply serrate outline, distinct on the margins as far back as the ovary, dorsally not usually distinct so far back as the ventral sucker; appendicular portion approximately equal to half the length of the body proper; neck short, tapering, slightly arcuate. The rami of the intestine enter the appendiculate portion when the latter is extended. In some which have the appendix retracted the intestines appear to stop at the anterior end of the appendix. Mouth ventral; ventral sucker about twice the diameter of the oral sucker. Genital aperture at posterior ventral border of oral sucker; cirrus smooth, cirrus-pouch rather slender, reaching usually to about the middle of the dorsal side of the ventral sucker; prostate large, extending from dorsal side of ventral sucker posteriorly for a greater distance than the diameter of the ventral sucker. The seminal vesicle is relatively large, oval, and is inclosed in a muscular wall; it lies dorsal to the posterior end of the prostate and immediately in front of the testes. The testes are 2, small, globular, close together, ventral and slightly diagonally placed. The ovary lies some distance behind the testes, its longer diameter transverse to the axis of the body. At its posterior border lie the 2 yolk-glands, the right being globular or oblong elliptical, the left more or less 3-lobed. The folds of the uterus are for the most part between the seminal vesicle and the base of the appendix. The excretory vessels are not distinct in the mounted specimens.

This distome agrees closely with *Hemiurus appendiculatus* as described by Looss (Zool. Jahrb., 1907, p. 103, plate 7, figs. 1, 2, 3). The most marked difference is in the character of the seminal vesicle, which is not divided into two portions, but consists of a single, oval structure, inclosed in a strong, muscular wall and with its longer axis coinciding with the long axis of the body.

Host, *Clupanodon pseudohispanicus:* July 10, 1906, few.

Dimensions, life: Length 2.94; breadth 0.5; oral sucker 0.09; pharynx 0.07; ventral sucker 0.21; ova 0.027 by 0.010.

Sterrhurus monticellii (Linton). (Figs. 139, 140.)

Distomum monticellii, Proc. U. S. Nat. Mus., pp. 518–520, plate XLIV, figs. 2–8. Bull. U. S. Fish Commission, 1899, pp. 451, 473, 482. Bull. Bureau of Fisheries, vol. XXIV, p. 334, figs. 154, 155, 158.

The distomes upon which this description is based were collected from a remora which had been taken on a tiger shark before I reached the laboratory, and had been preserved in formalin. The stained and mounted material shows but a part of the anatomy, but so far as can be seen they agree with the species which I have recorded under the name *Distomum monticellii.* This distome agrees closely with the genus *Sterrhurus* Looss.

Following are the characters that can be made out from these distomes: Body smooth, nearly cylindrical, largest near posterior at level of ovary; ventral sucker 2.5 times the diameter of oral sucker; seminal vesicle elongated, situated at cephalo-dorsal border of ventral sucker and preceded by the prostate. Intestinal rami long. Testes small, close together, one behind the other and close to the posterior edge of the ventral sucker; ovary larger, separated from the testes by folds of the uterus; yolk-glands 2, at posterior border of the ovary, each rather deeply lobed; uterus filling a large part of the body.

Dimensions, balsam: Length 1.45; breadth 0.35; oral sucker 0.12; pharynx 0.06; ventral sucker 0.35; ova 0.02 by 0.01.

Transverse and tangential sections were cut of these distomes; of these the tangential were the most satisfactory. From them it was seen that there is a seminal receptacle situated caudo-dorsad of the yolk-glands. There is a deep cleft (fig. 139 *n*) on the ventral side of the neck, immediately in front of the ventral sucker, which has a thick, muscular wall at its inner end. The genital pore is close behind the oral sucker.

The folds of the uterus are closely compacted. The lateral excretory vessels appear to meet above the oral sucker. There does not appear to be an upper lip, as is shown in Looss's various closely allied genera. Fig. 139 is a sketch of a tangential section through the head and neck. It shows the cirrus, portions of the seminal vesicle, prostate gland, metraterm, cleft in front of ventral sucker, with its thickened muscular wall at the inner end, an ovum in the common genital duct, oral sucker, pharynx, intestine and excretory vessel.

Host, *Neomænis griseus:* July 4, 1908, 1 fish, 1 distome.

Dimensions, life: Length 1.20; breadth 0.35; oral sucker 0.11; pharynx 0.04; ventral sucker 0.28; ova 0.012 by 0.006.

Host, *Echeneis naucrates:* June 24, 1907, 1 fish, 8 distomes.

Host, *Abudefduf saxatilis:* July 7, 1907, 1 fish, 1 distome.

Dimensions, life: Length 1.05; breadth 0.25; oral sucker 0.10; pharynx 0.04; ventral sucker 0.16; ova 0.017 by 0.010.

Host, *Ocyurus chrysurus:* July 12, 1907, 3 fish, 2 distomes.

Dimensions, life: Length 1.26; breadth 0.40; oral sucker 0.10; pharynx 0.06; ventral sucker 0.24; ova 0.016 by 0.011.

Host, *Chlorichthys bifasciatus:*

July 8, 1907, 1 fish, 1 distome, immature.

Dimensions, life: Length 0.46; breadth 0.19; oral sucker 0.07; pharynx 0.03; ventral sucker 0.11.

The specific relations of this young distome are doubtful. There is a distinct prepharynx represented in the sketch made at the time of collecting. The specimen was lost.

Sterrhurus fusiformis (Lühe). (Figs. 141–147.)

The general appearance of this distome is much like that of the species I have recorded under the name *Distomum monticellii*, but the vitelline glands are more numerously and more deeply lobed than in that species. It appears to agree closely with *Lecithochirium fusiformis* Lühe (Zool. Anz. XXIV, p. 476, fig. 3). Looss refers this species to the genus *Sterrhurus* Looss (Zool. Jahr., 1907, p. 143, figs. 52, 55, 56).

Body in general fusiform, but very variable; pale red or flesh-color, body reddish, neck translucent yellowish (a specimen which had been lying under the cover-glass for 2 hours or more was pale greenish-yellow by transmitted light); neck short, frequently arched or abruptly folded ventrally on itself; ventral sucker rather more than twice the diameter of the oral sucker; esophagus very short; pharynx contiguous to oral sucker. The rami of the intestines may reach to the cephalic end of the large excretory organ in the appendix. Genital aperture ventral to the caudal end of the pharynx; cirrus-pouch muscular, surrounded by large prostatic cells; seminal vesicle at its caudal end irregularly pyriform, in front of and dorsal to the ventral sucker. Testes 2, small, nearly transversely placed and near the caudal border of the ventral sucker. Ovary subglobular or oval, not lobed, situated about the middle of the length of the body; vitelline glands adjacent to and behind the ovary, made up of 7 slender-clavate branches uniting in an attenuated middle part. There appear to be 7 of these branches, 4 on the right and 3 on the left side. The seminal receptacle is oval, behind the ovary and dorsal to and touching the vitelline glands; uterus in many folds in the mid-region of the body, extending from the caudal end of the body proper to the ventral sucker. The metraterm enters the cirrus-pouch (figs. 146, 147). Excretory vessel voluminous and thick-walled in the appendix, passing as a single vessel to the caudal border of the ventral sucker, where it divides into 2 lateral vessels. These lateral branches unite dorsal to the oral sucker.

Host, *Lycodontis moringa:*

1906, July 4, 1 fish, 4 distomes, in stomach.

1907, July 2, 1 fish, 1 distome; July 11, 1 fish, 3 distomes.

Dimensions, life: Length 3.50; breadth 0.91; oral sucker 0.25; pharynx 0.07; ventral sucker 0.56; ova 0.018 by 0.009.

Host, *Lycodontis funebris:*

1906, July 4, 1 fish, 150 ± distomes, stomach.

1907, June 28, 2 fish, 82 distomes, stomach.

When placed in sea-water these distomes adhere strongly to each other and to individuals of other species.

Dimensions, life: Length 3.5; breadth, anterior 0.28, middle 0.90, posterior 0.28; oral sucker 0.22; pharynx 0.07; ventral sucker 0.50; ova 0.02 by 0.01.

Mature and immature occurred together in these lots.

Ectenurus virgula sp. nov. (Fig. 148.)

This species, according to Pratt's Synopsis, belongs to the genus *Lecithocladium*. When one attempts to give it a place among the numerous genera established by Looss (Beitrag zu Syst. d. Dist.) it must be placed in or near the genus *Ectenurus*, on account of the 2 lateral eminences (fig. 148 *n*) situated on the dorsal side of the neck above the pharynx.

The following description is based on specimens mounted in balsam:

Body cylindrical to fusiform with transverse rings making a sharp serrate outline which is most conspicuous on the ventral side, where it continues caudad to about the base of the appendix, very faint on the dorsal side; appendix approximately one-third of the entire length; neck short, its diameter much less than that of the body, with 2 slight eminences dorsal to pharynx; ventral sucker prominent, 2.5 times the diameter of the oral sucker; pharynx subglobular, adjacent to oral sucker; rami of intestine extend into the appendix. Genital aperture ventral, median, at posterior margin of oral sucker; cirrus slender, about as long as the diameter of the ventral sucker; cirrus-pouch dorsal to ventral sucker, prostatic portion rather small and inconspicuous, somewhat variable in position but always behind the ventral sucker, its long axis coinciding nearly with the long axis of the body. Seminal vesicle divided usually into 3 parts, which, in most cases, increase in size posteriorly, the anterior division ellipsoidal, the others subspherical, the whole vesicle surrounded by a definite muscular wall. There is considerable variation shown by the seminal vesicle. Testes 2, close together, one behind the other, just back of the seminal vesicle and with but a short interval between the posterior one and the ovary, somewhat variable in shape but in the main subglobular; in some cases equal, in others the posterior is the larger. Ovary near, in some cases, touching, the posterior testis; in some cases larger, in others equal to, and in others smaller, than the posterior testis, usually ellipsoidal with longer axis transverse to the long axis of the body. Yolk-glands tubular, lying beside the ovary and extending a little way both in front and behind the ovary. In one case there appeared to be only 2 of these tubular glands. In others there were more, possibly as many as 4. The yolk-glands are much convoluted and consequently difficult to make out. The seminal vesicle, testes, ovary, and yolk-glands are all ventrally situated. The folds of the uterus for the most part lie dorsal to the other genitalia and behind them, extending as far back as the base of the appendix. The metraterm was not seen satisfactorily. It appears to lie dorsal to the base of the cirrus-pouch, thence it was traced along the left side of the cirrus-pouch to the base of the retracted cirrus. The excretory vessels do not show distinctly in the mounted specimens, but it could be made out that they end blindly lateral to the oral sucker.

Dimensions, life, flattened: Length 3; diameter 0.5; oral sucker 0.15; pharynx 0.08; ventral sucker 0.38; ova 0.017 by 0.008.

Host, *Clupanodon pseudohispanicus:* July 10, 1906, numerous.

Ectenurus sp., immature. (Fig. 155.)

The specimens in this lot, which are small and immature, are near *Ectenurus* (fig. 148). The following description is based on specimens mounted in balsam:

Body nearly linear; neck cylindrical, arched; neck and body crossed by fine, transverse lines making a serrate outline; ventral sucker about 1.5 times oral. There is a slight projection of the head beyond the oral sucker. There seems to be a very short esophagus and the intestinal rami extend to the extreme posterior end. In one specimen the intestines are convoluted in the tail region (fig. 155); in another they are straight. Genital aperture ventral to the subglobular pharynx; cirrus-pouch long, inclosing the seminal vesicle, the latter lying behind the ventral sucker. Testes 2, close together and just behind the seminal vesicle.

Ovary a short distance behind the testes, oval; vitelline glands tubular, beginning at the ovary and extending some distance back of it. In two of the specimens the tail was inclosed in a sheath as shown in the sketch (fig. 155). In the third specimen the tail was narrower than the body and tapered uniformly to the posterior end.

Dimensions of specimen figured: Length 2; breadth 0.28; length of neck 0.35; oral sucker 0.16; pharynx 0.07; ventral sucker 0.25.

Host, *Auxis thazard:* July 10, 1906, 1 fish, 3 distomes.

Dinurus rubeus sp. nov. (Figs. 149–154.)

This species resembles *Dinurus longisinus* Looss, but differs from that species in having a preoral projection and in the character of the seminal vesicle, which is without constrictions.

Body elongated, cylindrical; color somewhat variable, but in most cases tinged with red in the middle portions; the intestines dark brown, nearly linear in middle region but tapering gradually to the posterior end; neck short; head with short, conical projection in front of oral sucker; ventral sucker about twice oral; pharynx subglobular, contiguous with oral sucker, its lumen quadrangular; esophagus short; intestinal rami ample, sacculate, extending to the posterior end, in my specimens filled with black, granular material. Genital aperture median, ventral to pharynx; cirrus short; prostate large, its tube much convoluted; in my specimens the prostate begins at the anterior edge of the ventral sucker and extends to the posterior edge; seminal vesicle behind ventral sucker. Testes 2, near posterior edge of ventral sucker, slightly diagonally placed; ovary subglobular or oval, a short distance behind testes; seminal receptacle behind ovary and close to it; vitelline glands tubular, lateral, beginning a short distance in front of ovary and continuing for a short distance back of the seminal receptacle; uterus voluminous, mainly dorsal and median, from level of testes back rather more than half-way from the ventral sucker to the posterior end; ova very numerous and minute. The metraterm joins the duct of the prostate at base of the retracted cirrus in a specimen studied in sections (fig. 152). Excretory vessel single, from posterior end to a point a short distance behind seminal vesicle, where it divides into two lateral branches which unite above oral sucker. The cells lining the excretory vessel near posterior end appear to be ciliated. Length 5 to 25 mm.; diameter 1 to 2 mm.

Host, *Lycodontis moringa:* 1907, June 30, 1 fish, 1 distome.

This distome was translucent greenish-white, intestines black. Neck actively contractile, body less so. There were a few, low, fleshy papillæ scattered over the surface of the body.

Dimensions, life: Length 5.5; breadth 0.98; oral sucker 0.42; pharynx 0.28; ventral sucker 0.84; neck, extended, length 1.40, breadth 0.35. Ova, balsam, 0.018 by 0.010.

1907, July 2, 1 fish, 1 and fragment.

Suckers transparent greenish, from ventral sucker to posterior yellowish, due to ova, posterior third very dark; length 25 mm.

Host, *Lycodontis funebris:*

1906, July 4, 1 fish, 3 distomes in stomach, 1 in intestine.

Middle of body tinged with red, anterior end translucent whitish or greenish-yellow; intestines conspicuous, black; length of largest 22; diameter 1.5 to 2; oral sucker 0.98; pharynx 0.42; ventral sucker 1.92. Ova, balsam, 0.017 by 0.010.

1907, June 28, 2 fish, 2 distomes, in stomach, 8 and 16 mm. long.

1908, July 7, 1 fish, 3 distomes.

Length 15 and 18 mm. respectively. General ground-color reddish, especially in the middle third, growing paler toward the posterior end and becoming translucent anteriorly in the vicinity of the suckers; intestines black, conspicuous the entire length.

Hapladena varia gen. et sp. nov. (Figs. 156, 157.)

Etymology: ἁπλόος, single; ἀδήν, gland.

Body, especially anteriorly, covered with dense, short, flat spines; shape variable, fusiform to linear; suckers nearly equal and not far apart;

pharynx usually about half the diameter of oral sucker. There is a distinct prepharynx and an esophagus. The proportions of the prepharynx and esophagus are variable (figs. 156, 157). The forking of the intestines is, in some cases, on a level with the ventral sucker, in others behind it. The rami of the intestines reach nearly to the posterior end of the body. Genital aperture in front of ventral sucker and near it. There is a conspicuous cirrus and cirrus-pouch, the latter inclosing the convoluted seminal vesicle and prostate, extending dorsal to the ventral sucker and behind it. There is but one testis, which is relatively large, especially in the younger adults, and is situated about the posterior third. The ovary lies a short distance in front of the testis. It is an oval or subspherical body, and, like the testis, lies on the median line. It is preceded by the conspicuous shell-gland, on the right and ventral side of which there is a seminal receptacle. The folds of the uterus lie between the ovary and the ventral sucker. The vitelline glands are diffuse and lie along the margins at the posterior end, and are scattered through the median region of the body. They extend forward about to the ventral sucker.

Host, *Teuthis hepatus:*

1907, July 1, 1 fish, 3 distomes.

1908, July 11, 1 fish, 14 distomes; July 13, 3 fish, 17 distomes; July 15, 1 fish, 9 distomes.

In some the spinose cuticle was separating from the body; intestines frequently dark brown. In one lot there were thought at first to be three distinct species: (1) Translucent, plump, cylindrical, old specimens. Dimensions, lying free in water: Length 2.66; breadth 0.70; oral sucker 0.21; pharynx 0.07; ventral sucker 0.21; ova 0.042 by 0.024. (2) Opaque, white, thickish. Dimensions, compressed: Length 2.87; breadth 0.97; oral sucker 0.21; pharynx 0.08; ventral sucker 0.26; ova 0.045 by 0.027. (3) Flat, thin, faint greenish-yellow, translucent, apparently younger forms of the foregoing but with fewer ova. In these there was a great variety of outline, especially of the anterior end, tapering, bluntly rounded, and a few knobbed by a constriction just behind the oral sucker. The opaque forms, before compression, were often truncate and had a strong tendency to slough off the epidermis.

One slender, immature distome had the following dimensions: Length 1.50; breadth 0.40; oral sucker 0.12; pharynx 0.06; ventral sucker 0.10.

Host, *Teuthis cæruleus:*

1908, June 27, 1 fish, 1 distome; July 6, 1 fish, 5 distomes.

Dimensions, life, flattened: Length 3; breadth not recorded; oral sucker 0.27; pharynx 0.14; ventral sucker 0.27; ova 0.04 by 0.02.

DERADENA gen. nov.

Etymology: *δέρη*, neck; *ἀδήν*, gland.

Body smooth. Vitellaria diffuse, posterior, and lateral, in most cases entirely behind ventral sucker and not reaching to the anterior border of the ventral sucker in any of the species here described. Testis one, oval, or somewhat triangular in outline, on median line towards the posterior end of the body; ovary oval, not lobed, in front of testis;

genital aperture median, in front of the ventral sucker; ova large. The character which suggests the name of the genus is the presence of conspicuous glands in the neck, which are interpreted to be yolk-forming cells.

Deradena ovalis gen. et sp. nov. (Figs. 162–169.)

The following description is based on whole mounts and sections of specimens from *Scarus cæruleus:*

Body smooth, oval, thickish, pale red, suckers about equal, neck about 0.25 of entire length; pharynx longer than wide; esophagus relatively long; bifurcation of intestine not far from posterior edge of ventral sucker, the rami extending to the posterior end. Genital aperture at anterior border of ventral sucker; no penis; genital pouch containing the comparatively straight and strong-walled metraterm, which, near the outlet, receives a small tube from the seminal vesicle (fig. 164 *z*) and is dorsal to the ventral sucker; prostatic cells accompany both metraterm and seminal vesicle. There was considerable difference in details in the two series of sections as shown in figs. 164 and 165. One testis, large, near posterior end of body. Ovary in front of testis and near it, nearly median, its vertical diameter greater than the lateral; shell-gland ventral and median to the ovary, as seen in sections; in whole mounts it is on the anterior and lateral border of the ovary. In one of the whole mounts the shell-gland extends along the entire anterior border of the ovary and about half-way back on each lateral border. In the other it is so much obscured by the vitellaria that it is difficult to see it at all. The vas deferens is voluminous and was traced in sections from the posterior end of the cirrus-pouch to the shell-gland. There is a large seminal receptacle which is situated for the most part ventral to the shell-gland. No Laurer's canal was recognized in the sections. The vitellaria are very abundant and are distributed peripherally throughout the body. Large cells extend from the body-wall into the parenchyma (fig. 168 *d*). At their inner ends they are yolk-bearing (fig. 169 *d* and *d'*). I interpret the cell to which the index line *d'* points as having undergone nuclear division, and the inner nucleus with the mass of yolk surrounding it as about to separate. The masses of yolk (fig. 169 *vg*) forming a concentric layer within the layer of yolk-forming cells can be seen to be made up of cells which resemble the inner ends of such cells as *d'*. These yolk-cells tend to fuse together, their nuclei disappear, and the yolk is at first reduced to a granular condition, as in the duct *yd* seen in longitudinal section in fig. 169. Next it collects into coarse granular masses, as in the duct *yd*, shown in cross-section in fig. 169. The folds of the uterus lie between the ovary and the ventral sucker. There is a distinct excretory pore at the posterior end of the body, and a straight excretory vessel appears in the series of sections on the dorsal side as far forward as the anterior border of the testis. My notes, made at the time of collecting, mention in one of the specimens the occurrence of dark, lateral lines meeting behind the ventral sucker whence the single tube extends to the posterior end. Some very small vessels, which appear in the transverse sections but which I have been unable to trace to the posterior single vessel, may represent the excretory vessels in the anterior part of the body. The body-wall is rather thick and the musculature is well developed.

Dimensions of mounted specimen: Length 3.50; breadth 1.12; length of neck 0.88; oral sucker, length 0.48, breadth 0.46; pharynx, length 0.21, breadth 0.14; ventral sucker, length 0.42, breadth 0.48; ova 0.054 by 0.027.

Host, *Scarus cæruleus:* July 13, 1908, 2 fish, 3 distomes.

Host, *Scarus* sp. (This was a parrot-fish having many points of resemblance to *Sparisoma abildgaardi.*)

July 11, 1908, 1 fish, 2 distomes.

Pale red, thickish, with lateral dark lines meeting behind ventral sucker. Dimensions, flattened: Length 5; breadth 2.5; oral sucker 0.56; pharynx, length 0.43, breadth 0.35; ventral sucker 0.86; ova 0.047 by 0.034.

July 8, 1908, 1 fish, 1 distome.

Not in good condition. Ova 0.09 by 0.06.

The distomes here recorded probably represent different species.

Host, *Scarus croicensis* (?): July 8, 1908, 2 fish, 1 distome.

Specimen in poor condition. Fusiform, no ova.

Dimensions: Length 1.12; breadth 0.67; oral sucker 0.22; pharynx 0.15; ventral sucker 0.35.

Host, *Scarus croicensis:* July 7 and 8, 1908, 3 fish, 1 distome.

Dimensions in glycerin, flattened: Length 2.10; breadth 0.77, oral sucker 0.29; pharynx 0.07; ventral sucker 0.49.

Deradena acuta gen. et sp. nov. (Figs. 158, 159.)

Distomum sp., from *Tylosurus acus*. Parasites of Bermuda Fishes, Proc. U. S. Nat. Mus., XXXIII, p. 115, fig. 62.

This species bears a superficial resemblance to *Haplosplanchnus* Looss, but the vitellaria are diffuse instead of dendritic.

Body fusiform, broadest in middle, whence it tapers to each end, the posterior end being rather the more slender. Ventral sucker at about anterior third, nearly twice the diameter of the oral, its aperture narrow and nearly coinciding with the axis of the body. There is a short prepharynx and an esophagus. The pharynx is slightly pyriform. The genital aperture is close behind the pharynx and a little to the left of it. The cirrus-pouch proper is adjacent to the genital aperture and is nearly circular in outline. What seems to be the prostatic portion and the metraterm lies on the right side of the ventral sucker. A characteristic striated appearance of the cirrus-pouch, noted in the living specimen, is evident in the mounted specimen, both in the globular portion and in the slender prostatic portion. The rami of the intestine appear to extend nearly to the posterior end. Two glandular bodies at the antero-lateral borders of the ventral sucker (fig. 159 *d*) are interpreted to be yolk-forming glands. The vitellaria are dense and diffuse, filling the greater part of the body behind the ventral sucker. They extend about as far forward as the middle of the ventral sucker. In the stained specimen they are a rich reddish-brown, and lie in dense masses between and to some extent over the other organs. There is a single large testis which is somewhat triangular, with the pointed end directed caudad. The ovary lies on the anterior border of the testis. It is oval, its longer diameter transverse, and it is much smaller than the testis. The seminal receptacle lies on the left side, extending from the ovary along the margin to a point a little behind the level of the posterior edge of the ventral sucker. The folds of the uterus lie behind the ventral sucker and between that organ and the ovary. The ova are large and not numerous.

Host, *Tylosurus marinus:* July 9, 1906, 1 fish, 2 distomes.

Dimensions of larger specimen, life, moderately compressed: Length 1.96; breadth, anterior 0.22, middle 0.66, posterior 0.11; oral sucker 0.21; pharynx, length 0.12, breadth 0.09; ventral sucker, length 0.40, breadth 0.35; ova 0.071 by 0.054. Length of smaller specimen 1.50.

The body was smooth, but with a few small nodular papillæ at the anterior end.

Deradena obtusa gen. et sp. nov. (Figs. 160, 161.)

The specimens here figured and described may belong to different species. They are in poor condition and but little of the anatomy could be made out. Body smooth, fusiform, tapering to each end, but rather more posteriorly than anteriorly. The rami of the intestine extend to the posterior end. The pharynx is adjacent to the oral sucker; ventral sucker larger than oral. Genital aperture between the suckers but nearer oral than ventral. Ovary and seminal vesicle at caudal border of ventral sucker. Testis one, conspicuous, occupying a large part of the space behind the ventral sucker. The vitellaria are diffuse, posterior, and marginal, and extend forward in front of the ventral sucker. In front of the ventral sucker there are lateral clusters of large, nucleated cells, which are interpreted as yolk-forming glands, as in the preceding species. The ova are few and large and lie dorsal to the ventral sucker. In the specimen figured from *T. cæruleus* they lie for the most part behind the ventral sucker.

Host, *Teuthis hepatus:*

1907, July 1, 1 fish, 3 distomes; July 11, 1 fish, 1 distome.

Dimensions, life: Length 1.22; breadth 0.50; oral sucker 0.19; pharynx 0.07; ventral sucker 0.24; ova 0.075 by 0.051.

Host, *Teuthis cæruleus:* July 6, 1908, 1 fish, 2 distomes.

Dimensions, life: Length 0.98; breadth 0.29; ventral sucker 0.16; ova 0.075 by 0.051.

MONOSTOMIDÆ.

Barisomum erubescens gen. et sp. nov. (Figs. 173–183.)

Etymology: *βᾶρις*, a boat; *σῶμα*, body.

Body smooth, convex dorsally, both transversely and longitudinally, and concave both transversely and longitudinally on the ventral surface. Viewed from the ventral side the body is boat-shape. The ground-color in life is pink; the excretory vessels usually, and the intestines often, filled with black, granular material. Oral sucker circular in outline, subterminal. A cross-section of the body behind the oral sucker is more or less circular, as is also a section made near the posterior end. In all intermediate portions of the body a transverse section is horseshoe-shaped (fig. 175). The lateral margins, beginning in 2 thick muscular folds a short distance behind the oral sucker, are bent downward and inward until the gap between the edges may be no more than one-third the whole breadth of the body thus folded. The edges are muscular, being provided with strong, longitudinal muscle fibers. The body throughout is supplied with numerous fascicles of strong muscle fibers which connect the morphologically dorsal and ventral surfaces (figs. 175, 178–180). There is no pharynx, but there is a slender esophagus (fig. 183). The intestinal rami extend to the posterior end, with numerous short branches throughout. In one set of sections they were observed to anastomose (fig. 177). In other sets of sections the rami of the intestines do not appear to anastomose, although their walls were seen in juxtaposition in two sets of sections. In the most satisfactory set they were entirely separated by parenchymatous tissue. The genital aperture is on the left margin approximately at the anterior third. The cirrus-pouch is relatively large, cylindrical, the basal half consisting of the conspicuous prostate. The seminal vesicle, as a convoluted tube, lies caudad of the basal portion of the cirrus-pouch and enters the distal end of the prostatic portion. The testes are 2, somewhat lobed, and lie opposite to each other at the extreme posterior end of the body. The ovary, also more or less lobed, lies on the median line a little in front of the testes, its posterior margin about on a level with the anterior edges of the testes. The seminal receptacle lies anterior and dorsal to the ovary, and the shell-gland is behind the ovary and between the testes. The vitelline glands are massed laterally on the margins immediately in front of the testes, extending from the anterior border of the testes for a short distance along the margin. The folds of the uterus lie in close, transverse loops running from margin to margin between the testes and the cirrus-pouch. The ova have a slender filament at each pole. The excretory vessels are conspicuous, being in most cases filled with black pigment, which remains in the mounted specimens. The excretory vessels begin at the head in a net-work of fine vessels. These soon unite into 2 main lateral branches about half-way between the mouth and the bifurcation of the intestine. They pursue a somewhat irregular, meandering course, but mainly lateral, to the posterior end, where they unite just before entering the excretory pore.

One of the most characteristic features of this singular worm is the musculature, especially as seen in the numerous fascicles of transverse fibers and in the strong marginal fibers (fig. 175 *tm*, *lm*).

Host, *Angelichthys isabelita:*

1906, July 10, 1 fish, 2 trematodes.

1908, July 3, 1 fish, 3 trematodes.

These trematodes were boat-shape, pinkish, anterior end lighter colored; dark-brown intestines, branched; genitalia white. Length 2.5 to 3 mm.

Host, *Pomacanthus arcuatus:*

1907, July 3, 1 fish, 1 trematode; July 11, 1 fish, 8 trematodes; July 15, 1 fish, 1 trematode.

Ground-color pink; body characteristically canoe-shape; intestine with black pigment, rami with numerous short branches. Length from 2.5 to 3.5 mm. A small specimen, flattened, had the following dimensions: Length 2.60; breadth, anterior 0.40, middle 0.80, posterior 0.70; oral sucker 0.20; oral aperture 0.07; ova, exclusive of filaments, 0.037 by 0.017; length of filament 0.30.

Host, *Scarus croicensis:*

1908, July 13, 2 fish, 1 trematode.

Much smaller than specimens from *Pomacanthus* and in poor condition; recorded here on account of its general appearance, character of the intestines, uterus and ova.

Himasomum candidulum gen. et sp. nov. (Figs. 184–197a.)

Etymology: *ἱμάς*, strap; *σῶμα*, body.

Body slender, nearly linear, thin, the edges usually folded under ventrally, especially towards the posterior end; color white. Head variable, a muscular collar or ridge separating it from the body; oral sucker nearly terminal. The muscular collar on the neck is sometimes contracted until it is simply a more or less prominent ridge; at other times it may be very prominent, with a thin, frill-like edge, which may be reflected (figs. 184*a*, 185–187). The musculature is less developed on the ventral surface back of the mouth, so that there is often the appearance of a deep notch, or even the entire absence of a collar. There is no pharynx; the esophagus is relatively long and quite slender. The rami of the intestine extend to the posterior end, where they pass mediad of the testes. Their posterior ends do not unite. In some cases the intestines appear to be slightly branched, especially near the anterior end, where the outlines seem to show that there were very short digitations on the intestinal walls. The walls may be quite irregular, but neither the mounted specimens nor the sectioned material shows a condition which will justify the statement that the intestinal rami are branched. Genital aperture on the left margin at about the anterior fifth. Cirrus rather long and smooth. The cirrus-pouch passes diagonally to the middle line, its dorsal half lying along the middle line and inclosing the prostate gland. The seminal vesicle is a slender, coiled duct posterior to the cirrus-pouch. Testes 2, lobed, lateral, opposite, at posterior end of the body, their anterior borders behind the level of the ovary. They are separated from each other by the excretory vessel and by the intestines. The ovary is lobed, nearly median, or a little to the right of the median line and a short distance in front of the testes. The shell-gland is posterior to the ovary, median and between the anterior portions of the testes. The vitellaria consist of a number of solid masses of irregular shape, but in general more or less rounded, beginning posteriorly at the anterior border of the testes and extending along each lateral margin to a point which is about as much in front of the ovary as that organ is in front of the posterior end of the body. The folds of the uterus begin behind the ovary at the shell-gland. Passing to the left of the ovary they occupy the median region of the body forward as far as the base of the cirrus-pouch. The folds are so disposed as to incline from their marginal limits postero-mediad to the median line. The muscular metraterm lies parallel with the proximal portion of the cirrus-pouch and on its posterior side. The ova are oblong elliptical with a long filament at each pole. The characteristic musculature of the preceding species (*Barisomum erubescens*) is seen in this species, though neither the fascicles nor the fibers are so strongly developed as they are in that species. The excretory vessels unite near the head above the esophagus. They pass laterad of the intestines until a short distance in front of the ovary, where they pass under the intestinal rami, then mediad to unite just behind the shell-gland. The single excretory vessel now passes between the testes and the posterior extremities of the intestines to the terminal excretory pore. Further anatomical details are given in the figures.

Host, *Angelichthys isabelita:* July 3, 1908, 1 fish, 1 trematode.

Host, *Pomacanthus arcuatus:*

1906, July 18, 1 fish, 5 trematodes.

1907, July 3, 1 fish, 4 trematodes; July 11, 1 fish, 48 trematodes; July 15, 1 fish, 7 trematodes.

1908, June 29, 1 fish, 7 trematodes; July 1, 1 fish, 4 trematodes; July 3, 2 fish, 18 trematodes; July 4, 2 fish, 4 trematodes; July 7, 2 fish, 4 trematodes.

Dimensions in glycerin: Length 2.46; breadth, anterior 0.08, middle 0.33, posterior 0.28; breadth 0.12 from anterior end 0.26; genital aperture 0.7 from anterior end; diameter of oral sucker 0.08; ova, exclusive of filaments, 0.034 by 0.017.

Length in most cases from 3 to 4.5 mm.

Dimensions of one of larger specimens, life, flattened and the posterior end unrolled: Length 4.69; breadth, anterior 0.36, middle 0.36, posterior 0.78; ova, exclusive of filaments, 0.033 by 0.017; length of filaments 0.42 ±.

PARAMPHISTOMIDÆ.

Cleptodiscus reticulatus gen. et sp. nov. (Figs. 198–204.)

Etymology: *κλέπτω*, to conceal; *δίσκος*, a quoit.

Outline of body somewhat variable but usually fusiform or long oval, tapering moderately to the rounded anterior end and narrowing very slightly towards the posterior end, which bears a round sucker ventrally placed. Body smooth, crossed by fine transverse lines which give to the surface a somewhat crinkly appearance; color white, sometimes tinged with red or pink, especially in the vicinity of the posterior sucker. Mouth terminal, provided with a muscular, pharynx-like sucker, which is glandular in its peripheral portion, at least supplied with numerous, deeply staining nuclei (fig. 200 *a′*). There are 2 small, rudimentary suckers at the postero-lateral border of the mouth-pharynx, which, however, can be seen only by deep focussing (figs. 201 *r* and 202 *r*). The esophagus is slender and surrounded by deeply staining nuclei (figs. 200 and 202 *n*), which are more abundant around its anterior portion. Rami of the intestine simple, extending to the posterior end, often inflated, especially at the distal ends. Genital aperture ventral, median, at bifurcation of intestines, surrounded by a muscular disk with abundant, deeply staining nuclei. The cirrus-pouch is oval and contains the pyriform cirrus and a few coils of the seminal vesicle. The prostate gland is not conspicuous and is represented apparently only by the not numerous cells in the cirrus-pouch. Testes 2, more or less lobed, situated about the middle of the body, one following the other and close to it, slightly diagonally placed. Vas deferens very long, in a coiled mass behind and ventral to the cirrus-pouch. Ovary small, subglobular, usually median and near the posterior end. Shell-gland at caudal border of ovary and between it and the anterior border of the posterior sucker. In one specimen both ovary and shell-gland were to the left of the median line, and those folds of the uterus which were immediately in front of the posterior sucker contained spermatozoa. The vitelline glands are represented by lateral clusters of irregularly rounded masses, somewhat variable in extent, but usually extending from a little in front of the posterior sucker to a point on a level with the middle of the posterior testis. The uterus extends from the shell-gland at the posterior end of the body to the coiled vas deferens, and the metraterm continues ventrad of the cirrus-pouch to open beside it at the common genital opening. The ova are relatively large and oval. The lateral excretory vessels unite above the esophagus just back of the mouth-pharynx, pass ventrad of the intestinal rami, and unite at the anterior border of the posterior sucker. The single excretory vessel now passes to the dorsal side of the posterior sucker, but the excretory pore was not seen. A light-gray non-staining mass above the mouth-pharynx and another smaller one below were noted, faintly indicated in fig. 202 *dh*, *rh*. They suggest nerve masses, but no cells were demonstrated in them. With the exception of these fine, granular, non-staining masses the parenchyma of the body consists of a loose network of fibers. The body-wall is rather weak, the cuticle, circular and longitudinal muscle layers each rather thin. Peripheral gland-cells few and scattering.

Dimensions in balsam : Length 3.78; breadth, anterior 0.14, middle 0.71, posterior 0.86; anterior sucker, length 0.14, breadth 0.11; posterior sucker, length 0.51, breadth 0.65. Dimensions of a smaller specimen: Length 1.60; breadth, anterior 0.14, middle 0.77, posterior 0.67; anterior sucker, length 0.14, breadth 0.11; posterior sucker, length 0.30, breadth 0.39. Ova in each 0.075 by 0.034.

Host, *Pomocanthus arcuatus:*

1906, July 18, 1 fish, numerous trematodes.

1907, July 3, 1 fish, 10 trematodes; July 11, 1 fish, 43 trematodes; July 15, 1 fish, 1 trematode.

1908, June 29, 1 fish, 60 trematodes; July 1, 1 fish, 18 trematodes; July 3, 2 fish, 65 trematodes; July 4, 2 fish, 190 trematodes; July 5, 2 fish, 13 trematodes; July 7, 2 fish, 52 trematodes in larger and 1 in smaller fish.

Dimensions, life: Length 1.65; breadth, anterior 0.21, middle 0.32, posterior 0.35; oral sucker, length 0.15, breadth 0.14; posterior sucker, length 0.46, breadth 0.30; ova 0.078 by 0.040. The length in general varied from 1.5 to 3.5.

SIPHODERIDÆ.

Siphodera (gen. nov.) vinaledwardsii (Linton). (Figs. 208, 209a.)

Monostomum vinaldwardsii, Linton, Bull. U. S. Fish Commission 1899, p. 470, figs. 373–376; Bull. Bureau of Fisheries, vol. xxiv, 1904, p. 370 and 410; Proc. Nat. Mus., xxxii, p. 118, fig. 97.

Etymology: σίφων, a tube; δέρη, neck.

Two trematodes from *Ocyurus chrysurus* appear to belong to this species. The most striking difference between them and specimens from *Opsanus tau* and from *Ocyurus chrysurus* in Bermuda is in the character of the testes. The right testes agree with the descriptions already published, but on the left side instead of 4 or 5 testes there is but 1. Until the limits of variability are better known it does not seem advisable to place this form in a new species.

In order to compare this with specimens in my collection, and at the same time taking advantage of the opportunity thus afforded to revise the description of the species, I made sections of old material and therefore can make a few needed emendations and corrections in the original description. I am still obliged to leave one point in the anatomy not entirely cleared up, viz., the real nature of the tube-like structures in the neck.

EMENDED DESCRIPTION OF THE SPECIES.

Body thickish, depressed, slightly convex above, flat below, outline varying, but approximately ovate, covered with exceedingly minute villous spines. Oral sucker circular, subterminal, the aperture nearly circular. Pharynx varying in preserved specimens, subglobular in life, near oral sucker but in favorable positions it is preceded by a short prepharynx. Esophagus short; intestinal rami extending to posterior end of body. The ventral sucker is a part of the genital apparatus (cirrus) and is depressed in a circular pit of the body-wall. The border of this pit is muscular and has strong, muscular fibers radiating from it. Contiguous with the genital sucker, dorsal or a little in front of it, is a muscular, subglobular portion lined with coarse, wedge-like masses resembling the lining of the prostatic portion of the cirrus-pouch in many of the distomes figured in this paper. Since this portion is surrounded by a few cells which appear to be prostate cells, this is doubtless the real nature of the structure. This portion is followed by a tubular seminal vesicle with muscular walls. Towards its posterior end it is more or less convoluted. On the right side of the undoubted seminal vesicle is a larger, oval seminal vessel, which is probably the seminal receptacle, although of this I am not quite certain. Posteriorly it lies dorsal to the ovary. A structure which appears to be Laurer's canal was noted in one set of sections. Testes variable, but usually 4 or 5 on each side. They begin from about the middle of the length to the posterior third and extend from the point of beginning approximately half-way to the posterior end. The ovary is many-lobed and situated on the median line a short distance behind the genital sucker, from which it is separated by the seminal vesicle. The vitelline glands in the older specimens are confined mainly to the lateral regions of the middle third of the body; in younger specimens they are distributed generally in the posterior part of the body behind the genital sucker. They are dendritic, or, in the older specimens, represented by small, compact masses. The excretory vessels begin anteriorly in 2 lateral vessels beside the oral sucker. These branches unite dorsal to the ovary a little in front of the middle. Thence a single median vessel extends to the posterior end, near which it enlarges into a muscular excretory vessel. The living worm is characterized by having numerous, conspicuous, small, tube-like structures in the neck. These were wrongly called excretory vessels in the original description of the species. I am not altogether sure of their real nature, but have reason to think them to be similar to the cells which elsewhere in this paper are called yolk-forming cells. In sections they are seen to be slender, long-pyriform, and pyriform bodies, not staining in hæmatein but staining strongly in orange G, with a fine granular structure. In transverse sections these pyriform bodies are peripherally placed with their small ends inserted in the body-wall. Nuclei were indistinctly seen in some of them. In the central portion of the sections of the neck were somewhat similar bodies but more coarsely grained and less elongated. In some of the sections the more coarsely granular bodies strongly suggest an intermediate stage between the fine granules of the peripherally placed bodies and the vitelline glands, as in the case of *Deradena ovalis* (fig. 169). If this is a correct interpretation we have here an example of yolk-forming cells in the neck. In that case the tube-like structures which appear to be penetrating the body-wall would turn out to be slender cells with the small ends peripheral and the large ends central, the resemblance to tubes penetrating the body-wall being deceptive. The folds of the uterus are very voluminous and fill up all the postero-median part of the body. In life the beginning folds on the left side are opaque-white, the next towards the posterior end on the right side are light yellow, shading into amber and smoky brown, becoming much darker toward the anterior. The metraterm was traced to the prostatic portion of the cirrus-pouch, but it was not seen to enter it. It appears to enter the genital pit in front of the genital sucker.

Dimensions of Tortugas specimen, life: Length 1.75; breadth 0.70; oral sucker 0.14; genital sucker 0.10; ova 0.017 by 0.007.

Host, *Ocyurus chrysurus:* July 10, 1907, 3 fish, 2 trematodes, one with ova and one without.

Stegopa globosa gen. et sp. nov. (Figs. 205–207.)

Etymology: *στέγω*, to protect; *ὀπή*, an opening.

The anatomy of these trematodes has been but imperfectly made out, mainly on account of the immense number of ova which obscure the various organs. The following incomplete description, it is to be hoped, will make future recognition of these minute forms possible.

Body nearly spherical; oral sucker three or more times the diameter of the genital sucker; pharynx adjacent to oral sucker about equal to genital sucker; intestine not seen; genital sucker median; cirrus, cirrus-pouch, and seminal vesicle not made out; testes 2, transverse or nearly so on opposite sides of the genital sucker; vitellaria mainly lateral and dorsal in the anterior half of the body. The ovary is deeply lobed and lies behind the testes. An oval body lying dorsally and in front of the genital sucker may be a cirrus-pouch, but was too indistinctly seen to be determined satisfactorily. The uterus fills the greater part of the body and the very numerous ova conceal and obscure the other organs.

Dimensions in balsam: Length 0.55; breadth 0.42; diameter of oral sucker 0.24; pharynx 0.07; ventral (genital) sucker 0.07; ova 0.011 by 0.007.

Host, *Neomænis griseus:* July 5, 1906, 11 fish, few trematodes.

Dimensions, life, flattened: Length 0.67; breadth 0.58; ova 0.020 by 0.013(?).

These trematodes bear a close superficial resemblance to *Distomum monorchus* Stoss. (Bull. Soc. Adr. Trieste, vol. XII, plate XV, fig. 62.)

Metadena crassulata gen. et sp. nov. (Fig. 210.)

Etymolgy: μετά, among; ἀδήν, gland.

The specimens here described when first seen were oval and rather thick. They were killed over a flame under pressure. The following description is based on a single very much flattened specimen.

Body oval, covered with exceedingly minute, short, bristle-like spines; oral sucker relatively large; pharynx adjacent to oral sucker; esophagus short; intestinal rami extend to near the posterior end. Genital aperture on median line, a little in front of the middle of the length, a little broader than long; cirrus-pouch lies caudad and the large seminal vesicles cephalad of the genital sucker. Testes two, oval, lateral, opposite, their anterior borders about at the middle of the length of the body. The ovary is many-lobed and situated in the middle of the body behind the cirrus-pouch and between the testes. The vitelline glands are lateral and extend from the level of the anterior edges of the testes to a point about on a level with the seminal vesicle, or a little in front of it and nearly opposite the bifurcation of the intestine; vitellaria also median between the marginal lobes and the genital sucker and seminal vesicle. The uterus is very voluminous and is filled with ova which obscure the other organs. Excretory vessels not made out except to note that the excretory pore is surrounded by radiating muscular fibers.

Dimensions in balsam: Length 1.83; breadth 1.25; oral sucker, length 0.42, breadth 0.39; pharynx 0.15; genital sucker, length 0.12, breadth 0.15; ova 0.017 by 0.009.

Host, *Neomænis analis:* July 1, 1908, 1 fish, 2 large and 1 small trematode.

Prodistomum gracile gen. et sp. nov. (Figs. 211, 212.)

Etymology: προ, in sense of for, instead of.

The specimens on which this description is based were in poor condition and the anatomy could be only imperfectly made out.

Body oval, clothed throughout with dense, slender spines; genital sucker about equal to oral and situated at about the anterior fourth of the length. The pharynx is adjacent to the oral sucker: esophagus is relatively long and slender. The bifurcation of the intestine is near the anterior border of the genital sucker. The rami of the intestine could be traced but a short distance on account of the dense vitellaria. The cirrus-pouch is oval, on middle line, its long axis corresponding with the long axis of the body, immediately behind the genital sucker, and followed at its caudal end by the seminal vesicle. Testes 2, oval or subglobular, on the median line, one following the other and close to it, and near the posterior end. Ovary oval-elliptical, on middle line in front of the anterior testis. There is a yolk-reservoir between the ovary and the anterior testis. The vitelline glands are diffuse and extend from the posterior end to within a short distance behind the genital sucker. The uterus lies between the ovary and the genital sucker; ova rather large. The terminal excretory pore is conspicuous and surrounded by a characteristic rosette-like arrangement of the muscles.

Host, *Clupanodon pseudohispanicus:* July 10, 1906, 2 trematodes.

Dimensions of smaller, life: Length 1.4; breadth, anterior 0.11, middle 0.30, posterior 0.19; oral sucker 0.09; pharynx 0.05; genital sucker 0.09; ova 0.061 by 0.047.

GENOLOPA gen. nov.

Etymology: γένος, sex; λοπάς, a dish.

Body covered with minute spines. Vitelline glands compact, lateral, near middle of length of body; 1 testis; ovary in front of testis, neither testis nor ovary lobed; cirrus relatively large, spinose; seminal vesicle inclosed in cirrus-pouch; folds of uterus mainly in the posterior part of the body behind testis; metraterm ample, muscular, joining cirrus at or in front of ventral (genital) sucker.

Genolopa ampullacea gen. et sp. nov. (Fig. 213.)

Monostomum sp. from *Hæmulon flavolineatus* and *Bathystoma striatum*, Bermuda. Proc. U. S. Nat. Mus., xxxiii, pp. 118–119, plate xiv, figs. 92, 93.

Shape very variable, long oval, fusiform, vase-shape. The anterior end of specimens which have been compressed is usually broad, making the outline ovate, the broad end being anterior. In some uncompressed individuals there is a decided narrowing of the anterior end into an abruptly tapering neck. The body is covered with minute spines. The transverse diameter of the oral sucker is approximately one-fourth greater than that of the genital sucker, The latter is sometimes rather faint, so that measurements made on the living specimens are often too small. The pharynx is close to the oral sucker in specimens which have been compressed; in others there is a short prepharynx. The pharynx is longer than broad and there is a short esophagus. The rami of the intestines were indistinct beyond the middle of the body, but they extend to the posterior end. The genital sucker is not far from the anterior third and on the median line. The spinose cirrus curves around the anterior edge of the genital sucker, and the ample cirrus-pouch, inclosing the large prostate, and, at its posterior end, the seminal vesicle, lies along the right side of the genital sucker, and, extending back of it, curves to the left, so that the posterior end of the pouch usually lies on the median line behind the genital sucker. On the left side of the genital sucker is the ample, muscular-walled metraterm which opens, along with the cirrus, at the genital sucker. The single testis is relatively large and lies behind the cirrus-pouch; in flattened specimens it is crowded to the right side. Immediately at its anterior border is the ovary which is smaller than the testis and subglobular in shape. The seminal receptacle is situated near the base of the cirrus-pouch. The vitelline glands are rather compact, lobular masses lying at the margins in the middle of the length of the body. A yolk-duct runs from each to the vicinity of the seminal receptacle. The folds of the uterus are very voluminous and lie on left side of body between the metraterm and left vitelline gland. From this region they extend caudad, filling posterior half of body. The ova were of fairly uniform size in all the specimens measured from the different hosts in which this worm was found.

Host, *Hæmulon macrostomum:* June 28, 1907, 2 fish, 1 trematode.

Dimensions, life, flattened: Length 1.15; breadth 0.63; oral sucker 0.14; pharynx 0.04; genital sucker 0.12; ova 0.017 by 0.010.

Host, *Hæmulon plumieri:* July 7, 1907, 14 fish, few trematodes, from pyloric cæca.

Dimensions, life: Length 0.87; breadth 0.27; oral sucker 0.06; pharynx 0.02; genital sucker 0.03 (?); ova 0.017 by 0.010.

Host, *Hæmulon sciurus:* 1907, July 7, 4 fish; July 12, 3 fish, few trematodes.

Dimensions, life, flattened: Length 0.84; breadth 0.39; oral sucker 0.08; pharynx 0.03; genital sucker 0.04 (?); ova 0.017 by 0.013.

Genolopa truncata gen. et sp. nov. (Figs. 214–216.)

Body spinose, linear or long oval, variable, the anterior end usually truncate, posterior end blunt or blunt-pointed; oral sucker relatively large; pharynx close to oral sucker, though there appears to be a short prepharynx; esophagus as long, or a little longer than pharynx. Genital sucker a little in front of middle; cirrus spinose; cirrus-pouch and extremity of metraterm capacious; seminal vesicle inclosed in cirrus-pouch. There is 1 testis, oval or subspherical, median, behind cirrus-pouch; ovary on right side of testis and a little in advance of it. The vitelline glands are compact bodies near the margin on a level with the cirrus-pouch. The folds of the uterus fill up all the available space behind the cirrus-pouch; ova small, short-oval or elliptical.

This species resembles *Monostomum* sp. from *Orthopristis chrysopterus* (Parasites of Fishes of Beaufort, Bull. U. S. Fish Commission, XXIV, p. 379, fig. 223), but the ova are very different. In the Beaufort species the longer diameter of the ova is three times that of the shorter.

Host, *Hæmulon plumieri:*

1906, July 8, 1 fish, 1 trematode.

1907, July 5, 12 fish, 1 trematode; July 10, 12 fish, 1 trematode.

Dimensions, life, flattened: Length 0.96; breadth, anterior 0.22, middle 0.36, posterior 0.08; oral sucker, length 0.15, breadth 0.14; genital sucker 0.07; ova 0.017 by 0.010. Another: Length 1; breadth 0.23; oral sucker 0.27; pharynx 0.03; genital sucker 0.07; ova 0.014 by 0.010.

Host, *Hæmulon sciurus:* July 4, 1907, 4 fish, 1 trematode.

Dimensions in balsam: Length 0.51; breadth 0.32; oral sucker, length 0.17, breadth 0.11; genital sucker 0.09; ova 0.017 by 0.010.

GASTEROSTOMIDÆ.

Gasterostomum sp. (Figs. 219–221.)

This species is probably *G. gracilescens* Rudolphi, or near it.

The one specimen here noted proved to be so far advanced in the production of eggs that details of structure can not be made out. The body is blunt at the anterior end, where it terminates in a sucker which is but little narrower than the body. The anterior two-thirds is linear. At the anterior end of the cirrus-pouch the body begins to grow narrower and tapers thence to the posterior end. The vitellaria are lateral and occupy about the middle third of the length. They are compact, but are not in distinct, rounded masses of definite number, as is usually the case in this genus. The body is filled with ova from the posterior end to the anterior sucker.

Host, *Lycodontis moringa:* July 7, 1907, 1 fish, 1 trematode.

Dimensions, life: Length 1.61; breadth 0.57; anterior sucker 0.35; ova 0.027 by 0.017.

In balsam the length is 0.7, breadth 0.4, diameter of anterior sucker 0.3, and diameter of ventral sucker 0.06.

Gasterostomum sp. (Figs. 222, 222a.)

Body linear, anterior end truncate; anterior sucker about as broad as the anterior end of the body. Ventral sucker about middle of length; intestine oblong-elliptical. Testes equal, near median line, one in front and the other behind the ventral sucker and very near it. Ovary behind posterior testis, adjacent to it and a little to the right of the median line. The vitellaria are irregularly rounded masses, lateral and extending, from about the anterior end of the intestine, half-way to the anterior end of the body. Details of the structure of the cirrus-pouch could not be made out. The folds of the uterus lie between the ventral sucker and posterior end. The ova vary considerably in size and shape.

The species represented by this lot is nearer *G. baculum* than are those from *Mycteroperca venenosa.*

Host, *Mycteroperca bonaci:* July 11, 1906, 1 fish, numerous trematodes.

Dimensions, life: Length 2.52; breadth, anterior 0.21, middle 0.35, posterior 0.17; anterior sucker 0.17; ventral sucker 0.056; ova 0.034 by 0.024.

Other ova, in balsam: 0.034 by 0.020, 0.027 by 0.024, 0.027 by 0.020.

Gasterostomum sp. (Figs. 217, 217a, 218.)

Body linear, truncate, or capitate anteriorly, bluntly rounded posteriorly, covered with very minute spines; anterior sucker large, terminal, with conical base; genital sucker a little in front of the middle of body; esophagus short, intestine ovate. Testes 2, 1 behind genital sucker and close to it, the other a little farther caudad, nearly as far back as the anterior end of the cirrus-pouch; both nearly on the median line, the anterior the larger. The cirrus-pouch lies along the left side, ample, with small pyriform seminal vesicle inclosed in the anterior end (fig. 218 *sv*) and the prostate throughout its length. Ovary small, situated at the right of the genital sucker and a little caudad. Vitelline glands lateral, from level of genital sucker, or a little in front of it, in an irregular row, sixteen, more or less, globular bodies in each row. The folds of the uterus extend from the anterior testis to the posterior end. The ova are elliptical with rather thick shells. This description is based on the specimen sketched (fig. 217). There is considerable variation in the relative position of the testes and ovary.

This species bears some resemblance to *G. baculum* Linton.

Host, *Mycteroperca venenosa:*

1907, July 14, 1 fish, few trematodes.

1908, June 27, 1 fish, 10 trematodes.

Dimensions, in life, flattened: Length 0.95; breadth 0.21; anterior sucker 0.14; ventral sucker 0.04; ova 0.030 by 0.020. Dimensions of another, in balsam: Length 1.20; breadth 0.24; anterior sucker 0.15; ventral sucker 0.05; ova 0.03 by 0.02; distance from anterior end to ventral sucker 0.56.

Gasterostomum sp. (Figs. 223–225.)

Brief mention is here made of finds of this genus in the barracuda. Like all the representatives of this genus found by me at the Tortugas, they are in poor condition and it is impossible to make out details of the anatomy satisfactorily. It does not seem credible that such diverse forms as those shown in figs. 223, 224, and 225, can belong to the same species. Figure 225 was sketched from life, but neither it nor any specimen exactly like it appears among my stained and mounted material. Aside from this there is still a perplexing variety in the material collected from the barracuda.

In general these forms are characterized by having the anterior end elongated in front of the vitelline glands, with a rather small, but apparently anterior, sucker. Both fusiform and linear forms occur. The body is covered with exceedingly minute spines. A striking difference is found, among forms otherwise in close agreement, in the character of the ova. Indeed there seems to be greater diversity in the shape of the ova in the same species and even in the same individual in this genus than prevails among the distomes.

These specimens agree in having the vitellaria lateral to the genital sucker and in having the testes behind the genital sucker. Also the ovary is in front of the testes and on the right side in all. The testes do not agree either in relative size or in position. In fig. 223 they are relatively small and opposite; in fig. 225 they are relatively large and tandem. There is also variety in the position of the ovary, it being beside the genital sucker in fig. 224 and behind it in the others.

Host, *Sphyræna barracuda:*

1906, July 4, 4 fish, 6 trematodes; July 11, 2 fish, 1 trematode, small; July 15, 1 fish, 7 trematodes.

1907, July 10, 1 fish, 5 trematodes.

Dimensions, life, specimen shown in fig. 225: Length 1.48; length of posterior portion behind constriction 0.64; anterior sucker, length 0.11, breadth 0.16; ventral sucker 0.12; breadth of body, anterior 0.16, middle 0.33, posterior 0.12; ova 0.017 by 0.010.

Dimensions of a fusiform specimen, life: Length 1.33, breadth, anterior 0.07, middle 0.32, posterior 0.11; anterior sucker 0.07; ventral sucker 0.06; ova 0.020 by 0.014.

Dimensions of specimen belonging to the lot collected July 10, with ova as in fig. 224*a*: Length 1.12; breadth 0.28; anterior sucker 0.06; ventral sucker 0.04; ova 0.04 by 0.01.

HETERACOTYLEA.

Microcotyle incisa sp. nov. (Figs. 226–230.)

Body proper nearly linear, greatest diameter at about its junction with the sucker-bearing portion, narrowing from bifurcation of the intestine to the bluntly rounded anterior end; upper lip with a narrow emargination; anterior suckers oval-elliptical; posterior sucker-bearing portion tapering uniformly to the posterior end. The vitellaria are marginal from a point a short distance back of the intestinal bifurcation to the posterior end of the body proper, where the two lateral glands unite behind the testes and enter for a short distance into the sucker-bearing portion. The region of the vitellaria is plentifully sprinkled with small, black pigment spots which continue back of the testes dorsally in 4 parallel rows in the median third of the width for a little less than one-third the length of the sucker-bearing portion; about 8 larger pigment spots in 2 rows dorso-lateral to the esophagus. There are about 45 suckers in each row on the sucker-bearing portion, which portion equals a little more than one-third the entire length. There appear to be about 24 testicules which lie in an oval cluster at the base of the body proper. They are irregularly hexagonal in outline in one case, but more or less rounded in others. The ovary lies a short distance in front of the testes; it is best seen in dorsal view, when, as in specimen sketched, it appeared to be made up of a number of small lobes arranged in a wreath-like cluster.

Host, *Neomænis griseus:* 1907, July 9, 5 fish, 4 trematodes.

1908, July 1, 1 fish, 2 trematodes.

Dimensions, life: Length 2.40; length of body proper 1.40; maximum diameter 0.42, tapering to 0.14 at each end.

Another: Length 4.35; length of body proper 2.32; breadth, anterior 0.16, maximum, back of middle 0.56; anterior sucker, length 0.11, breadth 0.16; posterior suckers, length 0.12, breadth 0.08; ovum 0.18 by 0.07.

Udonella socialis sp. nov. (Figs. 238–241.)

This species is near *Udonella caligorum* Johnston, but is much smaller.

Body generally linear in outline, cylindrical; in some cases with transverse annulations, thus resembling a leech; anterior end somewhat truncate in contracted specimens. The 2 small, anterior suckers are ovate in outline; pharynx longer than broad. Ovary about middle of body, with large cells; testes, in the larger specimens, smaller than ovary, immediately behind and contiguous with it. The vitelline glands are lateral, subglobular bodies extending laterally throughout the greater part of the length. Near the posterior end of the body, 2 oval structures (fig. 238 *q*), agreeing in position with the posterior lobes of the vitelline glands, were seen in the larger individuals, which may represent yolk-reservoirs. They do not resemble the tubular organs represented in figures of *U. caligorum*. Posterior sucker cup-shape, circular, unarmed.

Adults, young, and eggs were attached to the two copepods. There were also numerous empty egg-capsules, from which the larvæ had escaped, a few with larvæ already developed, and a few with the larvæ in the act of escaping from the eggs (fig. 241 *e*, *j*, *k*).

Host, *Argulus* sp., in mouth of *Neomænis griseus:* 1908, July 4, 2 fish.

Two copepods in mouth of one of the fish; many trematodes and eggs of same attached to the 2 copepods.

Twenty trematodes were counted on the edges and ventral surface of one of the copepods, and there were others on the dorsal side. Each egg is fastened to its host by means of a filament which is attached to the smaller end. Dimensions, life: Length 0.71; breadth, anterior 0.14, middle 0.27, posterior 0.15; posterior sucker 0.21; ova 0.15 by 0.09. Dimensions of another, compressed: Length 1.82; breadth, anterior 0.27, middle 0.50, posterior 0.30; ova 0.21 by 0.11.

ASPIDOCOTYLEA.

Aspidogaster ringens Linton. (Figs. 236, 237, 237a.)

Bull. Bureau of Fisheries, XXIV, pp. 367, 397, figs. 243–249; Proc. U. S. Nat. M., XXXIII, p. 104, figs. 98, 99.

Only one specimen was found. It agrees closely with this species. There is the entire ventral lip with a median shallow notch, the lobed dorsal lip, and the 42 loculi around the border, with the marginal sense-organs between. The median ventral ridge is not evident in the mounted specimen. The pharynx is pyriform, the larger end directed posteriorly. The single testis is near the posterior end on the right side. The ovary is contiguous with the anterior end of the testis. Both ovary and testis are long-oval, the long axis of each corresponding to the long axis of the body. The vitellaria extend from the posterior end of the disk in two narrow lines on each side of the intestine, diverging slightly anteriorly and reaching to about the anterior third of the disk. Genital aperture on the left side of the neck.

The absence of a median ventral ridge does not justify the erection of a new species, since only one specimen was seen at the Dry Tortugas; moreover, many of the Beaufort specimens had very faint median ridges.

Host, *Calamus calamus:* July 11, 1908, 5 fish, 1 trematode.

Dimensions, life: Length 1.51; breadth, of head 0.42, of disk 0.86, of neck 0.31; pharynx, length 0.14, breadth 0.10; ova, variable, 0.075 by 0.045.

DEONTACOTYLEA.

Deontacylix ovalis gen. et sp. nov. (Figs. 231–235.)

Etymology: *δέοντα*, lacking; *κύλιξ*, a cup.

A few small trematodes are here described which appear to represent a new genus of certain affinities. It was nearly dark when I began to examine them, so that but few notes were made of the living specimens. They were afterwards stained, some in carmine and some in hæmatein, and mounted whole in balsam.

Body long-oval, flattened, tapering gradually to the anterior end and more abruptly to the posterior end. General color white, the branches of the intestine yellow. The mouth is minute, on the ventral side very close to the anterior end. The body is covered dorsally and laterally with minute, short, slender, rod-like spines in transverse rows, the rows about 0.009 mm. apart. There is no distinct oral sucker, no pharynx, and no ventral or other sucker present. The moderately narrow esophagus pursues a somewhat sinuous course to about the anterior third of the body, where it divides into two branches. These branches soon divide into two smaller branches, one extending forward and the other back. These secondary branches are somewhat irregular in outline, being short-sinuate or sacculate with one or more additional, shorter branches. The posterior rami reach to about the middle of the length of the body. Along the margin of the body there is a distinct border, finely granular and more lightly staining than the interior, and separated from the interior region by a light line having the appearance of a nerve. That is, 2 lateral nerves can be traced from a short distance behind the mouth, where they form a common band which crosses the esophagus dorsally and sends branches forward to unite again around the mouth, back to near the posterior end of the body.

The genital openings are close together and close to the posterior end on the dorsal side. A short tube (fig. 231 *m*) leads from its aperture, a little to the left of the median line, to a closely folded, tubular organ which appears to be the uterus. It is crowded with small, granular masses which are probably ova, although they do not look like any trematode ova that I have seen before. When isolated they are ovate, oval-elliptical, and pyriform, and there appears to be a thin shell. When highly magnified each ovum is seen to contain several coarse, granular masses of yolk (fig. 234). The cirrus (or ejaculatory duct) is short and leads from its opening near the opening of the metraterm to a seminal vesicle near the right border. In some specimens there was a tubular vas deferens without any noticeable enlargement into a seminal vesicle. The vas deferens could be traced forward between the uterus and ovary, then along the right side of the uterus to the testis (fig. 231 *vd*). A short distance in front of the seminal vesicle there is another seminal reservoir, which I take to be a seminal receptacle (fig. 231 *sr*). Along its median side a yolk-duct was seen, and a short distance in front and near the right side a small, deeply-staining lobed organ which appears to be the ovary. Concerning the limits of the other organs I am not quite certain. The vitelline glands appear to fill the greater part of the anterior half of the middle region of the body around the intestinal rami and with a greater dorsal than ventral distribution and are also distributed peripherally over the testes. The testes, while not altogether satisfactorily determined, appear to be diffuse organs lying ventrally in front of the folds of the uterus, extending laterally to the lateral nerves and forward between the posterior intestinal rami. The uterus is conspicuous and fills up the greater part of the posterior third of the body.

Host, *Kyphosus sectatrix:* July 16, 1907, 1 fish, few trematodes.

The longest specimen measured 4 mm. Dimensions of a smaller specimen, life: Length 2.24; breadth 0.77; diameter of mouth 0.06; ova, somewhat variable, 0.022 by 0.013.

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EXPLANATION OF PLATES.

The following reference letters have the same significance in the different figures unless otherwise indicated.

a. oral sucker.
b. ventral sucker.
c. cirrus, or ductus ejaculatorius.
cm. circular muscle.
cp. cirrus-pouch.
d. subcuticular gland-cells; in many cases these are interpreted to be yolk-forming cells.
dm. diagonal muscles.
e. ova.
exp. excretory pore.
exv. excretory vessel.
g. genital aperture.
i. intestine.
lm. longitudinal muscle.
m. metraterm, *i.e.*, the ejaculatory portion of the uterus.
o. ovary.
oe. esophagus.
p. prepharynx.
ph. pharynx.
pr. prostate.
pr'. duct of prostate.
sg. shell-gland.
sr. seminal receptacle.
sv. seminal vesicle.
t. testes.
tm. transverse muscle.
u. uterus.
vd. vas deferens.
vg. vitelline gland.
yd. yolk-duct.
yr. yolk-reservoir.

Figures 1 to 28 inclusive are from material collected from the loggerhead turtle; the remaining figures illustrate trematodes from various Tortugas fishes.

PLATE 1.

Cricocephalus delitescens Looss.

FIG. 1. Ventral view, life; some details added from stained and mounted specimen; intestine somewhat diagrammatic; length 4.6 mm. *f*, postero-lateral pit; *k*, muscular ridge.

FIG. 2. Enlarged view of one of the characteristic pits situated at lateral angles of truncated posterior end; actual diameter of pit 0.010 mm. From specimen mounted in balsam.

FIG. 3. Ovum; length of egg 0.029 mm., length of filament 0.12 mm.

Immature distomum. Related to Calycodes Looss.

FIG. 4. Ventral view, life; a few details added from mounted specimen; length 1.5 mm.

FIG. 5. Ventral view of anterior end of same; diameter of head 0.34 mm.

FIG. 6. Dorsal view of same.

Pachypsolus ovalis sp. nov.

FIG. 7. Ventral view. The specimen was flattened and the positions of some of the organs are somewhat changed from the normal; length 3.36 mm.

FIG. 8. Dorsal view of specimen reconstructed from sections.

FIG. 9. Transverse section of body at posterior edge of ventral sucker; diameter 0.84 mm.

FIG. 10. Transverse section at level of testes. Excretory vessels unite in next section posterior to this; diameter 0.88 mm.

PLATE 2.

Pachypsolus ovalis, continued.

FIG. 11. Nearly transverse section of the pharynx; diameter 0.14 mm.

FIG. 12. Sagittal section, diagrammatic, of cirrus-pouch, etc.

FIG. 13. Ova; maximum length 0.048 mm.

FIG. 14. Dorsal view, life, showing branching and anastomosing excretory vessels; length 4.4 mm.

Cymatocarpus undulatus Looss.

Fig. 15. Dorsal view of flattened specimen, life; length 3.57 mm. Ova in folds of uterus on right side and in posterior folds of left side dark brown, those in other folds of left side yellow. Metraterm surrounded by gland-cells resembling prostate gland.
Fig. 16. Ventral view, life, showing details of the genitalia.
Fig. 17. Transverse section of cirrus-bulb, showing prostate cells, part of seminal vesicle, and secretion in wall of prostatic duct; diameter 0.30 mm.
Fig. 18. Transverse section of neck showing esophagus and excretory vessel; diameter 0.86 mm.
Fig. 19. Transverse section just behind the bifurcation of the intestine; diameter 0.87 mm.

Plate 3.

Cymatocarpus undulatus, continued.

Fig. 20. Ova; length 0.024 mm.
Fig. 21. Excretory pore and surrounding glandular cells; diameter of pore 0.04 mm.
Fig. 22. Portion of transverse section of neck, showing yolk-forming cells and accumulating yolk in central parenchyma. Thickness of worm at this point 0.15 mm. *y*, accumulating yolk.

Orchidasma amphiorchis (Braun) Looss.

Fig. 23. Ventral view of specimen mounted in balsam; length 2.3 mm.
Fig. 24. Details of genitalia, dorsal view; breadth of body at level of anterior testis 0.63 mm.
Fig. 25. Ova; diameter 0.039 mm.
Fig. 26. Spines from cirrus; length 0.05 mm.
Fig. 27. Spines from metraterm; length 0.040 mm.
Fig. 28. Spines from distal end of metraterm; length 0.05 mm.

Trematodes from Fish.

Helicometra torta sp. nov., from *Epinephelus striatus*.

Fig. 29. Ventral view, life, flattened; length 4 mm.

Plate 4.

Helicometra torta, continued.

Fig. 30. Dorsal view of another specimen, not much flattened; length 1.57 mm.
Fig. 31. Surface view, life, ventral; length 2 mm.
Fig. 32. Details of ovary etc., of another specimen, life, ventral view; diameter of posterior testis 0.27 mm. *k*, oötype.
Fig. 33. Portions of ovary, shell-gland and yolk-reservoir, with oötype, from section; diameter of oötype 0.03 mm. *e'*, germ cell entering oötype.

Helicometra execta sp. nov.

Fig. 34. Dorsal view, life, details added from mounted specimen; length 1.90 mm.

This and the following figures, with the exception of 38*d*,
from *Hæmulon plumieri*.

Fig. 35. Ventral view of another specimen; length 1.50 mm.
Fig. 36. Cirrus-pouch and metraterm from longitudinal section. *n*, cells surrounding genital aperture.

Plate 5.

Helicometra execta, continued.

Fig. 37. Transverse section of cirrus-pouch and metraterm at anterior border of ventral sucker.
Fig. 38. Ovary and testes from different specimens.
Fig. 38*a*. Ovary in contact with single testis, latter not lobed.

FIG. 38*b*. Deeply lobed ovary separated from the 2 testes, one of the latter lobed.
FIG. 38*c*. Ovary, no testis present.
FIG. 38*d*. Ovary and single testis in contact; from *Hæmulon sciurus*.

All dorsal views, and drawn to the same scale.

FIG. 39. Filamented ovum; length of ovum 0.051 mm., length of filament 3 mm.

Helicometrina nimia gen. et sp. nov. All except fig. 48 from *Neomænis griseus*.

FIG. 40. Ventral view of stained and mounted specimen; length 2.70 mm. Excretory vessel added from another specimen. This is the usual arrangement of testes, viz., 5 on right and 4 on left side.
FIG. 41. Ventral view of a smaller specimen; length 1 mm. In this case there are 5 testes on left and 4 on right side.
FIG. 42. Dorsal view of neck of another; length of neck 0.50 mm.
FIG. 43. Ventral view of neck of another; length of neck 0.74 mm.
FIG. 44. Diagrams showing variations of testes. *a*, usual plan; *b*, *c*, *d*, variations noted. All ventral view.
FIG. 45. Sagittal section through cirrus-pouch and metraterm; thickness of body at this point 0.30 mm. The ejaculatory duct is shown cut through in several places.

PLATE 6.

Helicometrina nimia, continued.

FIG. 46. Median portion of transverse section through cirrus-pouch and metraterm. Thickness of body at this point 0.24 mm.
FIG. 47. Ovum; length 0.043 mm.
FIG. 48. Dorsal view of young specimen from *Eupomacentrus leucostictus*; length 1 mm.

Hamacreadium mutabile gen. et sp. nov. (Figs. 49 to 54 from *Neomænis griseus*.)

FIG. 49. Dorsal view of flattened specimen, life, details added from stained and mounted specimen; length 2.62 mm.
FIG. 50. Ventral view of another specimen not much flattened; length 2.28 mm. Specimens of this shape when flattened under a cover-glass and killed over flame may assume shape shown in preceding fig.
FIG. 51. Young, ventral view, in balsam; length 1.37 mm.
FIG. 52. From memorandum sketch made at time of collecting.
FIG. 53. Sketch of 4 specimens showing variety of form.
FIG. 54. Horizontal section of cirrus-pouch. *lm*, longitudinal muscles of cirrus-pouch.

PLATE 7.

Hamacreadium gulella gen. et sp. nov., from *Neomænis griseus*.

FIG. 55. Ventral view, balsam; length 1.85 mm. *exv'*, the anastomosing vessels in the head appear to be excretory vessels, although their connection with the more prominent Y-shaped excretory vessel was not made out.

Hamacreadium consuetum gen. et sp. nov., from *Hæmulon plumieri*.

FIG. 56. Ventral view, life, details added from mounted specimen; length 1.90 mm.
FIG. 56*a*. Ovum.
FIG. 57. Sagittal section of cirrus-pouch; length 0.30 mm. *c*, ejaculatory duct; *e*, egg lying at junction of ejaculatory duct and metraterm.
FIG. 58. Dorsal view of cirrus-pouch; length 0.22 mm.
FIG. 59. Dorsal view of ovary and seminal receptacle and part of right testis; length of seminal receptacle 0.08 mm.

Lebouria crassigula sp. nov., from *Calamus calamus*.

FIG. 60. Ventral view, balsam; length 1.33 mm.

Hamacreadium oscitans gen. et sp. nov., from *Hæmulon plumieri*.

FIG. 61. Ventral view, life, details added; length 1.05 mm.

PLATE 8.

Hamacreadium oscitans, continued.

FIG. 62. Ventral view, life, details added; length 1.50 mm; from *Lachnolaimus maximus*.

FIG. 63. Ventral view, life, details added; length 1.12 mm. Ovary not distinctly seen. Cirrus-pouch turned to the left by the contraction of the neck. From *Anisotremus virginicus*.

FIG. 63*a*. Ovum; length 0.043 mm.

Megasolena estrix gen. et sp. nov., from *Kyphosus sectatrix*.

FIG. 64. Ventral view, life; length 3 mm.

Didymorchis latus gen. et sp. nov., from *Calamus calamus*.

FIG. 65. Ventral view, life, details added; length 2.03 mm.

FIG. 65*a*. Ventral sucker, balsam.

Enenterum aureum gen. et sp. nov. from *Kyphosus sectatrix*.

FIG. 66. Ventral view, life, details added; length 5 mm.

FIG. 67. Front-ventral view of head showing arrangement of lobes, life; diameter 0.5 mm.

FIG. 68. Horizontal section showing cirrus, prostate, seminal vesicle, and metraterm.

PLATE 9.

Enenterum aureum gen. et sp. nov.

FIG. 69. Horizontal section. One section of the series intervenes between this and the previous figure.

FIG. 70. Cirrus-pouch and metraterm, balsam, ventral view; diameter of . ventral sucker 0.5 mm., compressed.

Lepocreadium trulla (Linton) from *Ocyurus chrysurus*.

FIG. 71. Dorsal view, balsam; length 1.12 mm. The spines are evanescent.

FIG. 72. Ventral view, life, somewhat distorted by pressure; length 1.22 mm.

FIG. 73. Excretory pore at posterior end of body.

FIG. 74. Spines, length 0.006 mm.

Lepocreadium levenseni (Linton).

FIG. 75. Ventral view, life, details added; length 1.68 mm. Oral sucker invaginated. From *Epinephelus morio*.

FIG. 76. Muscular bulb of excretory vessel at posterior end of body; diameter of bulb 0.04 mm.

FIG. 77. Ventral view of specimen from *Mycteroperca venenosa*, life; length 2.75 mm.

PLATE 10.

Stephanochasmus casus sp. nov.

FIG. 78. Ventral view, life, details added; length 3.3 mm. Spines evanescent. From *Neomænis griseus*.

FIG. 79. Horizontal section; length 2.1 mm.

FIG. 80. Ovum, life; length 0.068 mm.

FIG. 81. Transverse section of ovum, showing characteristic contraction character; diameter 0.031 mm.

FIG. 82. Nearly horizontal section of cirrus-pouch showing seminal vesicle and cells of prostate.

FIG. 83. Nearly horizontal section of young specimen from *Ocyurus chrysurus;* diameter of section at ventral sucker 0.41 mm.

Stephanochasmus sentus sp. nov.

FIG. 84. Dorso-lateral view, life, details added; length 3.15 mm. Spines evanescent. Peculiar papillate character of neck due to degeneration changes following falling off of spines. From *Hæmulon sciurus*.

FIG. 85. Ovum showing characteristic ribbed appearance of collapsed ova; length 0.075 mm.

FIG. 86. Ventral view of head of specimen from *H. plumieri*. Diameter of head 0.15 mm.

Lechradena edentula gen. et sp. nov., from *Neomænis griseus*.

FIG. 87. Ventral view, life, details added; length 2.10 mm.

PLATE 11.

Mesorchis urna gen. et sp. nov.

FIG. 88. Ventral view, life, details added, uterus diagrammatic; length 2.5 mm. From *Pomacanthus arcuatus*.

FIG. 89. Dorsal view, balsam, excretory vessel diagrammatic and added from another specimen; length 1.5 mm. *l*, opening of Laurer's canal.

FIG. 90. Tangential section showing excretory pore, Laurer's canal (*l*), cirrus, seminal vesicle, ovary, shell-gland, etc.; thickness of body at this point 0.26 mm. Sketch made from 3 adjacent sections.

FIG. 91. From horizontal section, showing ventral sucker, metraterm, and cirrus-pouch; diameter of ventral sucker 0.14 mm.

FIG. 92. Transverse section, showing ventral sucker, metraterm, branches of excretory vessels, posterior end of one testis, uterus, and yolk-duct; breadth 0.4 mm.

FIG. 93. Transverse section near posterior end, showing single excretory vessel. *h*, wall of branch of excretory vessel which is cut through in next section anterior to this; breadth 0.4 mm.

Diplangus paxillus gen. et sp. nov., from *Hæmulon macrostomum*.

FIG. 94. Lateral view, life, details added; length 1.35 mm.

FIG. 95. Dorsal view, life, details added; length 1.47 mm.

FIG. 95*a*. Ovum; length 0.041 mm.

PLATE 12.

Diplangus paxillus, continued.

FIG. 96. Lateral view, life, details added, somewhat diagrammatic; length 1.38 mm. From *H. plumieri*. The prostatic portion of the cirrus-pouch also contains a part of the seminal vesicle.

FIG. 96*a*. Ova; length 0.041 mm.

FIG. 96*b*. Outline, showing a common form, lateral view; length 1 mm.

FIG. 97. Ventral view, life, details added; length 1.75 mm.

FIG. 98. Transverse section through pharynx and cirrus-pouch. From *H. sciurus*.

FIG. 99. Nearly transverse section through neck, showing subcuticular glands which seem to be yolk-forming glands. Thickness of body at this point 0.08 mm. From *H. plumieri*.

FIG. 100. Nearly transverse section through seminal vesicle, a few cells of subcuticular glands showing. Thickness of body here 0.01 mm. *sv'*, prostatic part of seminal vesicle.

FIG. 101. Nearly transverse section through prostate gland and seminal vesicle and ventral sucker. From *H. sciurus*.

Deretrema fusillus gen. et sp. nov.

FIG. 102. Ventral view, life, details added; length 2.10 mm. Uterus somewhat diagrammatic. Contents of esophagus deeply stained. From *Ocyurus chrysurus*.

FIG. 102*a*. Ova, life; length 0.034 mm. Left ramus of intestine appeared to pass ventrad of cirrus-pouch as indicated in sketch.

PLATE 13.

Deretrema fusillus, continued, from *Hæmulon macrostomum*.

FIG. 103. Ventral view, life, details added; length 1.68 mm.

FIG. 104. Dorsal view, balsam; length 1 mm.

FIG. 104*a*. Ova, one collapsed; length 0.04 mm.

Distomum fenestratum Linton, from *Hæmulon plumieri.*

FIG. 105. Ventral view, life; length 3.5 mm.
FIG. 106. Transverse section near posterior end, somewhat diagrammatic; breadth 0.25 mm.

Xystretrum papillosum gen. et sp. nov., from *Lactophrys triqueter.*

FIG. 107. Ventral view, balsam; length 3.5 mm. Folds of the uterus diagrammatic. The ova are really much more numerous than represented. *c*, cirrus extruded; *n*, ventral corrugated disk.
FIG. 107*a*. Spines from posterior border enlarged.
FIG. 108. Papillary spines lining mouth cavity; diameter of mouth 0.16 mm.
FIG. 109. Papillary spines on ventral sucker; diameter of ventral sucker 0.21 mm.
FIG. 110. Transverse ridges of ventral disk.
FIG. 111. Outline of vitelline glands.

Hysterolecitha rosea gen. et sp. nov., from *Teuthis hepatus.*

FIG. 112. Ventro-lateral view, life, details added; length 3.36 mm.
FIG. 113. Ovary and vitelline glands seen from right side; longer diameter of ovary 0.11 mm.

PLATE 14.

Hysterolecitha rosea, continued, from *Teuthis hepatus.*

FIG. 114. Ejaculatory duct, seminal vesicle, and metraterm, life; highly magnified. *pr*, cells surrounding genital aperture.
FIGS. 115, 116, 117. Sketches of ovary, vitelline gland, and seminal receptacle from different specimens.

Macradena perfecta gen. et sp. nov., from *Teuthis cæruleus.*

FIG. 118. Sketch made up from about 3 adjacent, horizontal sections, somewhat diagrammatic; length 2.55 mm.
FIG. 119. Part of transverse section through seminal receptacle, yolk-gland and shell-gland; diameter 0.45 mm.

Opisthadena dimidia gen. et sp. nov., from *Kyphosus sectatrix.*

FIG. 120. Ventral view, life, details added; length 2.80 mm.
FIG. 120*a*. Ova; length 0.038 mm.
FIG. 121. Dorsal view, made up from horizontal sections, diagrammatic; length 5 mm.

PLATE 15.

Opisthadena dimidia, continued.

FIG. 122. Transverse section showing extraordinary development of longitudinal muscles of body-wall and of walls of intestine; diameter 0.45 mm.

Brachadena pyriformis gen. et sp. nov.

FIG. 123. Ventral view, life, details added; length 1.61 mm. From *Hæmulon plumieri.*
FIG. 123*a*. Ovum; length 0.037 mm.
FIG. 124. Ventral view of small specimen, balsam; length 0.65 mm. From *H. sciurus.*
FIG. 125. Sagittal section of neck; diameter of oral sucker 0.010 mm. From *Calamus calamus.*
FIG. 126. Ventral view of cirrus-pouch, balsam. From *H. plumieri.*

Dichadena acuta gen. et sp. nov.

FIG. 127. Ventro-lateral view, balsam; length 1.55 mm. From *Teuthis cæruleus.*

PLATE 16.

Leurodera decora gen. et sp. nov.

FIG. 128. Ventral view, balsam; excretory vessel added from another specimen; length 1.86 mm. From *Hæmulon plumieri.*

FIG. 129. Free-hand sketch from life showing an inclosed nematode (*n*) near posterior end; length 1.75 mm.

Dictysarca virens gen. et sp. nov.

FIG. 130. Ventral view, diagrammatic and some details added from sections; length 4.5 mm. From *Lycodontis funebris. exp*, excretory pore surrounded by gland-cells; *u*, probably uterus, though no ova were present.

FIG. 131. Ventral view of anterior end of specimen with short esophagus, life; diameter of oral sucker 0.5 mm.

FIG. 132. Superficial view of alcoholic specimen; length 4.5 mm., breadth 2.5 mm., thickness 2 mm.

FIG. 133. Transverse section through cirrus-pouch, the next section behind this contains vertical part of metraterm; breadth 1.56 mm. Index line, *pr'*, points to duct of prostate.

FIG. 134. Memorandum sketch, life, ventral view showing the intestine and characteristic reticulated or areolated structure; length 5 mm. From *L. moringa.*

FIG. 135. Sagittal section, diagrammatic, of anterior end.

FIG. 136. Transverse section of body through ventral sucker; breadth 1.05 mm.

Theletrum fustiforme gen. et sp. nov.

FIG. 137. Lateral view, life, details added; length 1.83 mm. From *Pomacanthus arcuatus. w*, ventral papillæ.

PLATE 17.

Hemiurus merus sp. nov., from *Clupanodon pseudohispanicus.*

FIG. 138. Ventro-lateral view, balsam; length 1.66 mm.

Sterrhurus monticellii (Linton).

FIG. 139. Sagittal section of neck; diameter of oral sucker 0.12 mm. *h*, cleft in front of ventral sucker. From *Echeneis naucrates.*

FIG. 140. Immature specimen from *Chlorichthys bifasciatus*, life; length 0.46 mm.

Sterrhurus fusiformis (Lühe).

FIG. 141. Ventral view, balsam; length 2.52 mm. From *Lycodontis funebris.*

FIG. 142. Ovary and vitelline glands, dorsal view.

FIG. 143. Posterior end showing retracted condition; diameter 0.45 mm.

FIG. 144. Dorsal view, life, details added; length 1.96 mm. The oral sucker is invaginated. From *L. moringa.*

PLATE 18.

Sterrhurus fusiformis (Lühe), continued.

FIG. 145. Ventro-lateral view of body, dorsal of head, showing course of excretory vessels, life, details added; length 2.70 mm. The head is bent sharply ventrad. From *L. funebris.*

FIG. 146. Nearly sagittal section through cirrus-pouch, prostate, and metraterm; diameter of intestine 0.07 mm. *pr'*, duct of prostate; *cp'*, muscles of cirrus-pouch.

FIG. 147. Transverse section of cirrus-pouch; diameter of cirrus 0.05 mm. *cp'*, muscles of cirrus-pouch.

Ectenurus virgula sp. nov., from *Clupanodon pseudohispanicus.*

FIG. 148. Lateral view, life, details added; length 2.35 mm. *n*, lateral eminence on neck.

Dinurus rubeus sp. nov., from *Lycodontis funebris*.

FIG. 149. Superficial ventral view of specimen in alcohol; length 7.5 mm.
FIG. 150. Transverse section intestines with granular contents, single excretory vessels, uterus, ovary, shell-gland, seminal receptacle, and vitelline glands; diameter 1.18 mm.

PLATE 19.

Dinurus rubeus, continued, from *Lycodontis funebris*.

FIG. 151. Dorsal view, balsam; length 15 mm.
FIG. 152. Lateral view of cirrus, prostate, seminal vesicle, and metraterm; reconstructed from sections.
FIG. 153. Transverse section showing ventral sucker, prostate, metraterm, and excretory vessel; breadth 1.05 mm.
FIG. 154. Transverse section near posterior end, showing intestines and dorsal excretory vessel; diameter 0.72 mm.

Ectenurus (?) sp., immature, from *Auxis thazard*.

FIG. 155. Ventral view of immature specimen in balsam; length 2 mm.

Hapladena varia gen. et sp. nov.

FIG. 156. Ventral view, life, details added; length 3 mm. *f*, oötype. From *Teuthis cæruleus*.
FIG. 157. Ventral view of another specimen, life, details added; length 1.96 mm. *f*, oötype.

Deradena acuta gen. et sp. nov., from *Tylosurus marinus*.

FIG. 158. Ova, life, details added; length 0.071 mm.

PLATE 20.

Deradena acuta, continued.

FIG. 159. Ventral view, life, details added; length 1.166 mm.

Deradena obtusa gen. et sp. nov.

FIG. 160. Ventral view of specimen from *Teuthis hepatus*, life, details added; length 1.33 mm.
FIG. 161. Ventro-lateral view of specimen from *T. cæruleus*, life, memorandum sketch. The specimen when stained and mounted showed no more details than are given in the sketch. Length 0.98 mm.

Deradena ovalis gen. et sp. nov.

FIG. 162. Ventral view of specimen from *Scarus* sp. The anatomy was very poorly shown on account of the diffuse vitelline glands which obscured details of structure. Length 1.75 mm.
FIG. 163. Ventral view, balsam; length 3.5 mm. The vitelline glands were much denser than represented in sketch. Figs. 163–169 from *Scarus cæruleus*.
FIG. 164. Diagram of sagittal section of prostate, etc. *sv'*, communicating duct between seminal vesicle and common genital duct (*c*); *z*, point where seminal vesicle joins metraterm.
FIG. 165. Same view taken from another specimen. *z*, point where seminal vesicle joins metraterm; *c*, common genital duct.
FIG. 166. Transverse section through prostate made at *x* in fig. 165.
FIG. 167. Nearly transverse section made through *x* of fig. 164; *e*, ovum in common genital duct. Other reference letters as in fig. 164.
FIG. 168. Transverse section of body near posterior end; diameter 0.81 mm.
FIG. 169. From transverse section, showing active yolk-forming cells, *d'*, and different stages of the accumulation of yolk. See text for description.

PLATE 21.

Mesolecitha linearis gen. et sp. nov., from *Teuthis cæruleus.*

Fig. 170. Ventro-lateral view, life, details added; length 4.55 mm.
Fig. 171. Nearly horizontal view of ovary, shell-gland, filiform seminal receptacle, etc., made up from 3 or 4 horizontal sections.
Fig. 172. Sagittal section of cirrus, seminal vesicle, and metraterm, made up from 3 or 4 sections.

Barisomum erubescens gen. et sp. nov., from *Pomacanthus arcuatus.*

Figs. 173–173*c*. Sketches from life showing different specimens in various positions. Intestines dark brown or black, reproductive organs generally white, ground-color pink.
Fig. 173. Ventral view, lateral edges rolled under; length 2.5 mm.
Fig. 173*a*. Another, same view; length 3.25 mm.
Fig. 173*b*. Lateral view; length 3.25 mm.
Fig. 173*c*. Dorsal view; length 3.50 mm.
Fig. 174. Posterior end, ventral view; diameter 1.5 mm. The end has been cut, the lateral edges unrolled and spread apart. At *x* the intestine appears to be cut; if this is so the intestinal rami anastomosed at the posterior end.
Fig. 175. Transverse section, showing prostate, seminal vesicle, etc.; diameter 1.26 mm.
Fig. 176. Cirrus-pouch, prostate, etc., ventral view, edge turned under.
Fig. 177. Transverse section near posterior end, showing anastomosis of intestinal rami (this seems to be exceptional), ventral excretory pore and excretory vessel. Diameter 0.63 mm.

PLATE 22.

Barisomum erubescens, continued.

Fig. 178. Transverse section showing intestinal diverticula, strong transverse muscles, duct of prostate (no prostatic cells shown in this section), metraterm, and cirrus. Thickness of body at this point 0.22 mm. *m'*, cells surrounding metraterm.
Fig. 179. Transverse section showing duct of prostate, vas deferens, uterus, transverse muscles, etc. Thickness of body here 0.25 mm. *u'*, uterus with ova cut transversely.
Fig. 180. Transverse section showing fascicles of strong transverse muscles; thickness 0.19 mm.
Fig. 181. Transverse section of cirrus-pouch; diameter 0.14 mm.
Fig. 182. Ovum with filaments.
Fig. 182*a*. Ovum without filaments, more highly magnified; length of ovum 0.037 mm.; length of filament 0.30 mm.
Fig. 183. Dorsal view, life. The intestines, from the bifurcation to the level of the point marked *x*, were pink with clear granules; beyond this point they were filled with dark-brown or black granular contents. Length 2.6 mm.

Himasomum candidulum gen. et sp. nov., from *Pomacanthus arcuatus.*

Fig. 184. Ventral view, life, details added, folds of uterus diagrammatic; length 5 mm. *k*, muscular ridge.
Fig. 184*a*. Ventral view of head; diameter 0.32 mm.

PLATE 23.

Himasomum candidulum, continued.

Fig. 185. Ventral view of head of a different specimen from that sketched in fig. 184*a*; diameter 0.50 mm.
Fig. 186. Dorsal view of head with definite muscular ridge; diameter 0.43 mm.
Fig. 187. Dorsal view of head of another specimen with faint muscular ridge; diameter 0.28 mm.

FIG. 188. Dorsal view of esophagus, intestines, and excretory vessel. The dots, *tm*, represent fascicles of transverse muscles seen in section.

FIG. 189. Cirrus-pouch and metraterm, ventral view; diameter 0.90 mm. *k*, filaments of ova protruding from genital aperture. The ova are drawn on a slightly larger scale than remainder of sketch.

FIG. 190. Ventral view of posterior end, uterus diagrammatic; diameter 0.52 mm. The edges were turned under, but this was disregarded in the sketch to avoid confusion.

FIG. 191. Horizontal section of the head showing arrangement of muscles; diameter 0.20 mm.

FIG. 192. Plan of musculature of body-wall. There is an outer transverse (circular) layer, under this a longitudinal layer, and under this again 2 diagonal layers. The diagonal layers are of coarser fibers than the 2 outer layers.

FIG. 193. Section of cirrus and metraterm, from horizontal section of body, but nearly tangential of the marginal region at this point. Diameter of cirrus-pouch 0.05 mm.

FIG. 194. Tangential section of cirrus and prostate, tube of latter with prostatic secretion in elongated masses on walls. Diameter 0.11 mm.

FIG. 195. Transverse section of body in front of reproductive aperture, showing intestines, excretory vessels, and fascicles of transverse muscle fibers. Breadth 0.30 mm.

FIG. 196. Ova, apparently without filaments, from posterior end of body. Length 0.037 mm.

PLATE 24.

Himasomum candidulum, continued.

FIG. 197. Ovum with filaments, from folds of uterus in front of ovary.

FIG. 197*a*. Ovum greatly enlarged; length of ovum 0.037, of filament 0.42 mm.

Cleptodiscus reticulatus gen. et sp. nov.; from *Pomacanthus arcuatus*.

FIG. 198. Dorsal view, balsam, showing characteristic areolar structure; length 1.75 mm. *s*, posterior sucker showing from under side.

FIG. 199. Section of esophagus, nearly transverse; diameter 0.04 mm. *n*, cells surrounding esophagus.

FIG. 200. Sagittal section through oral sucker and esophagus; diameter of head at base of oral sucker 0.20 mm. *dh*, dorsal, and *vh* ventral granular masses; *a'*, cells in oral sucker; *n*, cells surrounding esophagus.

FIG. 201. Ventral view, life, details added; length 4 mm. *r,r*, rudimentary suckers; *s*, posterior sucker.

FIG. 202. Horizontal view of head showing rudimentary suckers *r*; *n*, cells surrounding esophagus. Diameter at level of rudimentary suckers 0.30 mm.

FIG. 203. Sagittal section through genital aperture showing cirrus-pouch, metraterm, vas deferens, intestine, portion of anterior testis, and characteristic areolar parenchyma. *i*, intestine with granular contents; *n*, cells surrounding genital aperture. Thickness of body at genital aperture 0.40 mm.

FIG. 204. Transverse section showing cirrus-pouch, metraterm, cells surrounding genital aperture, intestine, and excretory vessels. Diameter 0.45 mm.

Stegopa globosa gen. et sp. nov., from *Neomænis griseus*.

FIG. 205. Ventral view, life, details added; length 0.56 mm.

FIG. 206. Dorsal view of same.

FIG. 207. Ventral view of anterior end, life. Diameter of oral sucker 0.11 mm.

PLATE 25.

Siphodera (gen. nov.) ***vinaledwardsii*** (Linton), from *Ocyurus chrysurus.*

FIG. 208. Ventral view, balsam. Posterior end of excretory vessel supplied from a sketch from life. The crenulations did not appear and the longitudinal ribs were faint in mounted specimen. Uterus diagrammatic. Folds on right side are ventral and filled with dark-brown ova, those on left side are dorsal and filled with yellow ova. Tube-like gland-cells (*n*) in neck are more numerous than represented in sketch, and in sections are seen to be elongated cells similar to those represented in fig. 169. They are interpreted to be yolk-forming cells. Length 1.82 mm.

FIG. 209. Ventral view of genital sucker, prostatic portion of cirrus-pouch, and metraterm. *rm*, radial-muscle fibers; diameter of genital sucker 0.09 mm.

FIG. 209*a*. Diagram made up from sagittal sections of specimens from this host collected in Bermuda.

Metadena crassulata gen. et sp. nov., from *Neomænis analis.*

FIG. 210. Dorsal view, life, details added; length 1.83 mm.

Prodistomum gracile gen. et sp. nov., from *Clupanodon pseudohispanicus.*

FIG. 211. Ventral view, balsam; length 1.33 mm.

FIG. 212. Enlarged sketch of posterior excretory pore; diameter of muscular disc 0.04 mm.

Genolopa ampullacea gen. et sp. nov., from *Hæmulon macrostomum.*

FIG. 213. Ventral view, life, specimen much flattened; length 1.42 mm.

Genolopa truncata gen. et sp. nov., from *Hæmulon plumieri.*

FIG. 214. Ventral view, life, details added; length 0.96 mm.

FIG. 215. Ova; 0.017 by 0.010 mm.

PLATE 26.

Genolopa truncata, continued.

FIG. 216. Ventral view of another specimen, life; length 0.78 mm.

Gasterostomum sp., from *Mycteroperca venenosa.*

FIG. 217. Ventral view, life, details added; length 1.20 mm.

FIG. 217*a*. Ova, 0.027 by 0.020 mm.

FIG. 218. Posterior end, ventral view, balsam. Length of cirrus-bulb 0.7 mm. *n*, opening into cirrus seen through body-wall.

Gasterostomum gracilescens(?), from *Lycodontis moringa.*

FIG. 219. Anterior sucker, life; diameter 0.35 mm.

FIG. 220. Ventral view, balsam.

FIG. 221. Ova, life; 0.027 by 0.017 mm.

Gasterostomum sp., from *Mycteroperca bonaci.*

FIG. 222. Ventral view, life; length 1.90 mm.

FIG. 222*a*. Ova, balsam; 0.027 by 0.024 mm., 0.034 by 0.020 mm.

Gasterostomum sp., probably more than one species, from *Sphyræna barracuda.*

FIG. 223. Ventral view, life, a few details added; length 0.91 mm. *a*, ova, maximum length 0.024 mm.

FIG. 224. Ventral view; length 0.94 mm.

FIG. 224*a*. Ova, 0.03 by 0.01 mm.

FIG. 225. Ventral view, life. No others seen like this. The specimen was not found among the mounted material. Length 1.48 mm.

PLATE 27.

Microcotyle incisa sp. nov., from *Neomænis griseus.*

FIG. 226. Dorsal view, balsam; length 2.30 mm.
FIG. 227. Ventral view of head, balsam; diameter 0.09 mm.
FIG. 228. Dorsal view of head, balsam; diameter 0.09 mm. *n*, coarse pigment granules beside esophagus.
FIG. 229. Lateral view, life, caudal region distorted by pressure; length 2.4 mm.
FIG. 230. Two pairs of caudal suckers. Diameters of single sucker 0.06 and 0.03 mm.

Deontacylix ovalis gen. et sp. nov., from *Kyphosus sectatrix.*

FIG. 231. Ventral view, balsam; length 1.86 mm. *a*, mouth; *c*, ejaculatory duct; *n*, *n*, lateral bands uniting anteriorly above the esophagus and resembling nerves.
FIG. 232. Posterior end, dorsal view, of another specimen, balsam; diameter at level of ovary 0.6 mm.
FIG. 233. Ventral view of anterior end showing the minute mouth; greatly enlarged.
FIG. 234. Ova, highly magnified; 0.027 by 0.014 mm.
FIG. 235. Spines of body greatly enlarged; distance between rows of spines 0.009 mm.

PLATE 28.

Aspidogaster ringens Linton, from *Calamus calamus.*

FIG. 236. Ventral view, somewhat diagrammatic, life, details added; length 1.51 mm. There did not appear to be any longitudinal, median ventral ridge. *f*, marginal sense-organs; *h*, transverse ridges; *k*, marginal loculi.
FIG. 237. Ventral view of left margin. Coarse stippling represents nuclei of cells. Reference letters as in 236.
FIG. 237*a*. Right margin near anterior end, ventral view. Reference letters as in 236.

Udonella socialis sp. nov. on *Argulus* sp. in mouth of *Neomænis griseus.*

FIG. 238. Dorsal view of adult, balsam; length 1.20 mm. *e*, ovum in uterus; *q*, *q*, yolk-reservoirs (?).
FIG. 239. Ventral view of head, life; diameter of head 0.27 mm. *w*, mouth.
FIG. 240. Lateral view of head of small specimen, balsam.
FIG. 241. Posterior end of *Argulus* with trematodes, young and adult, and ova attached. Sketch made from specimen mounted in balsam. *ad*, adult; *j*, egg from which a young trematode is in act of escaping; *k*, egg-capsule from which the young has escaped; *l*, part of egg-chain of copepod; *y*, young.

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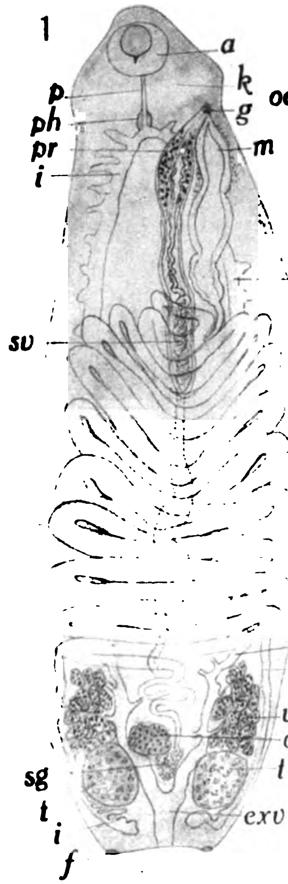

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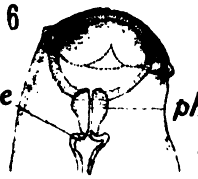

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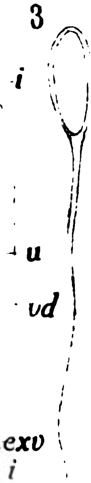

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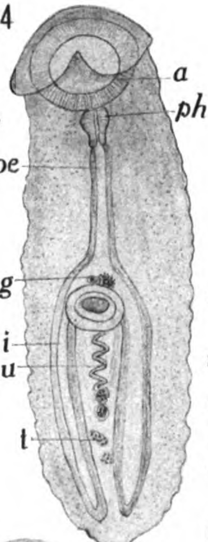

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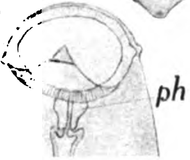

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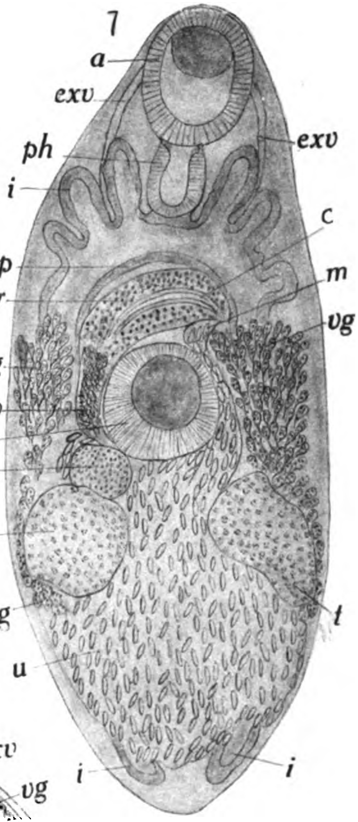

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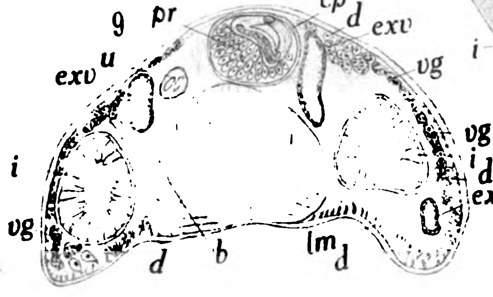

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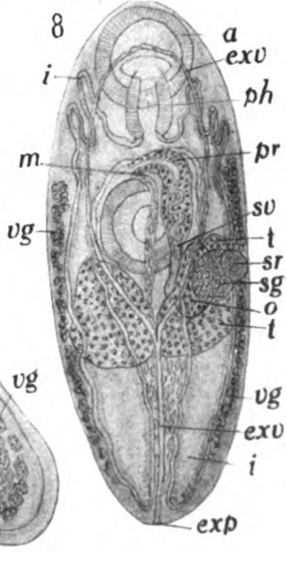

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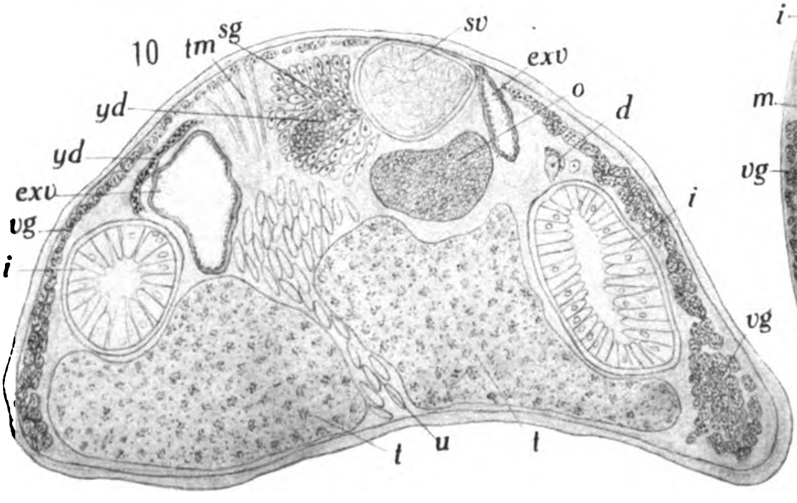

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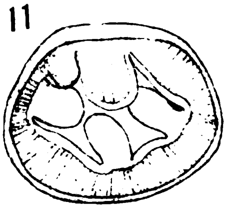

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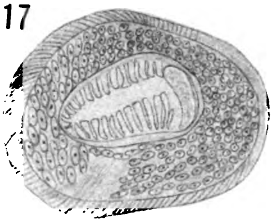

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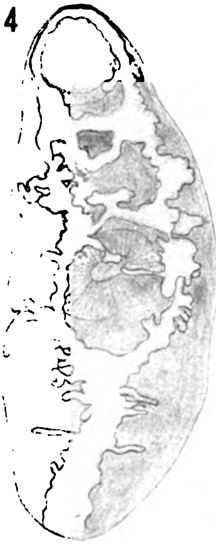

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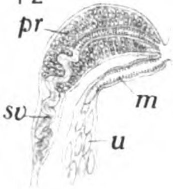

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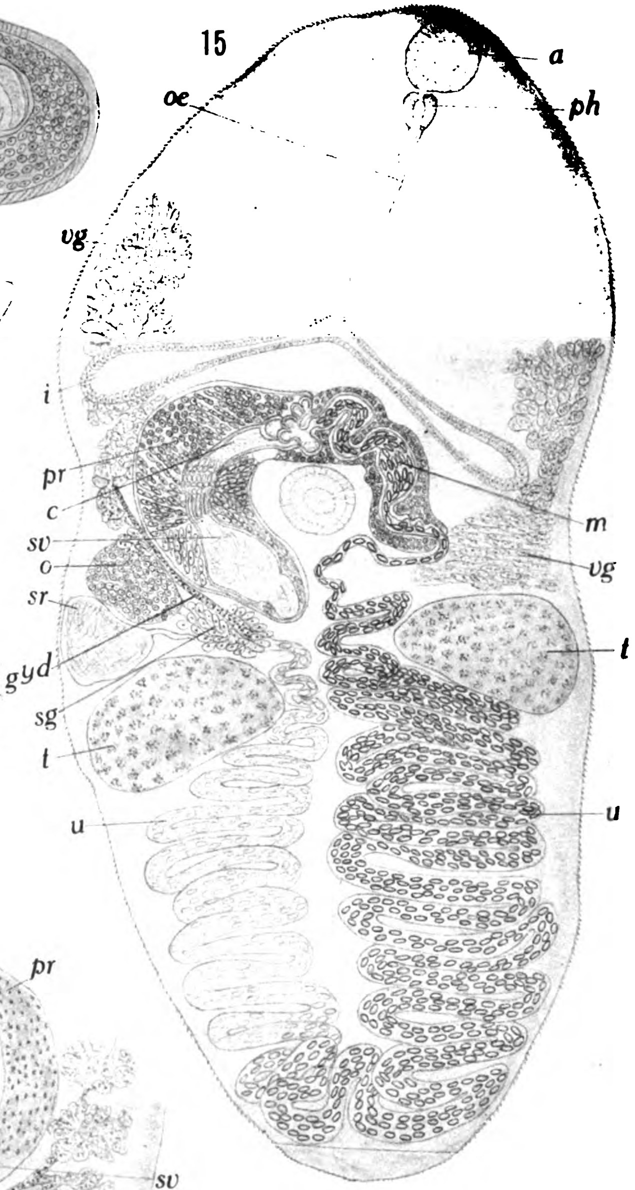

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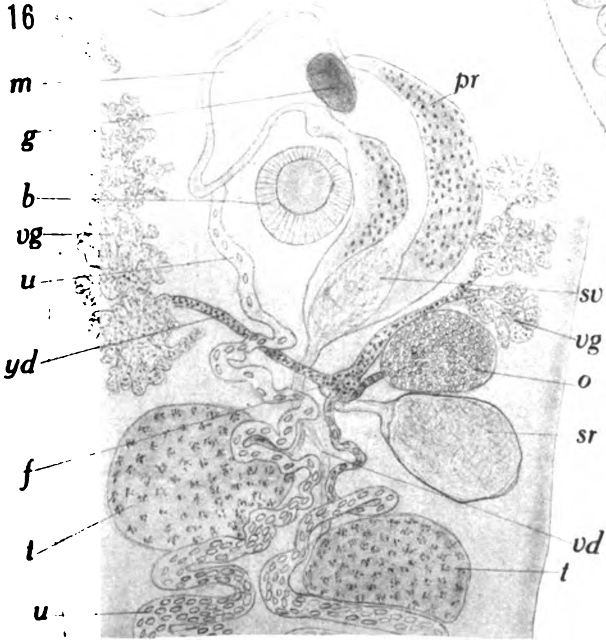

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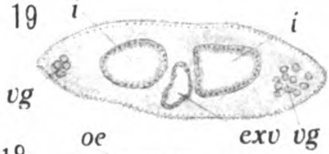

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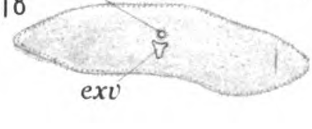

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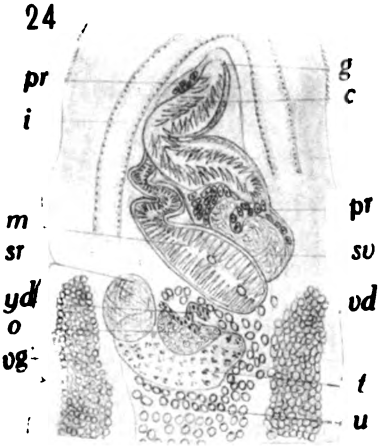

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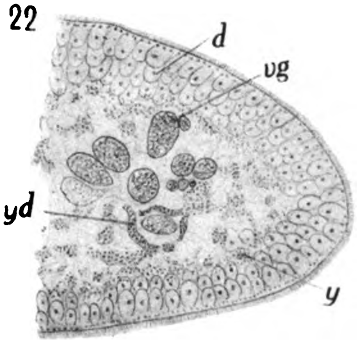

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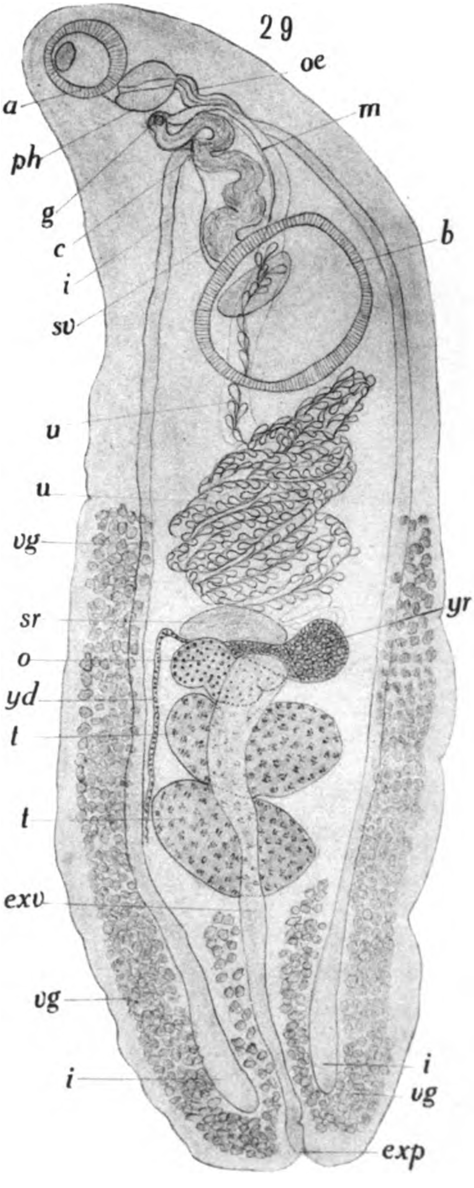

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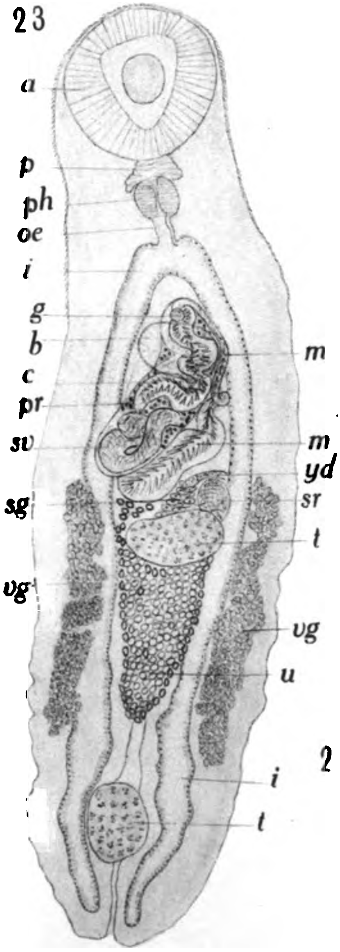

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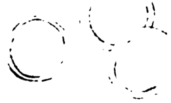

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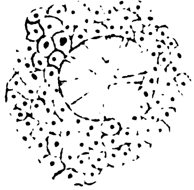

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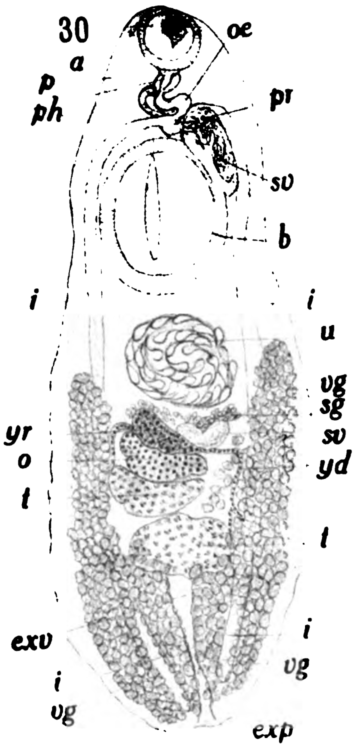

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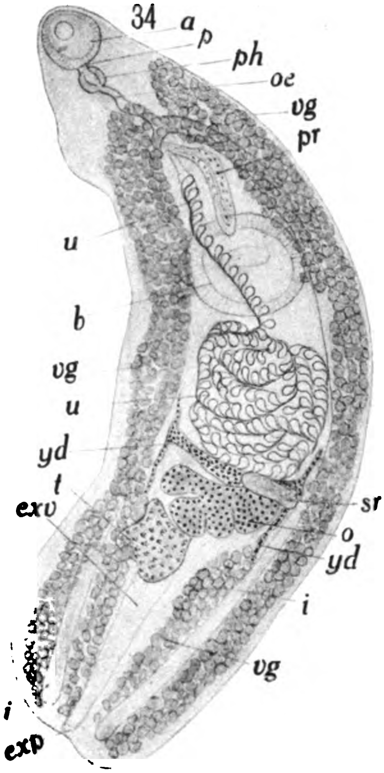

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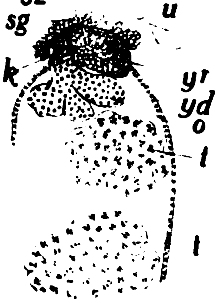

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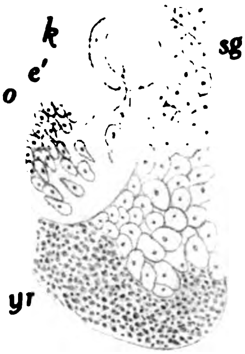

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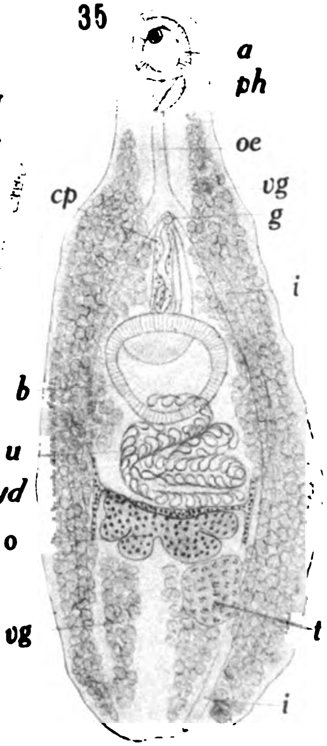

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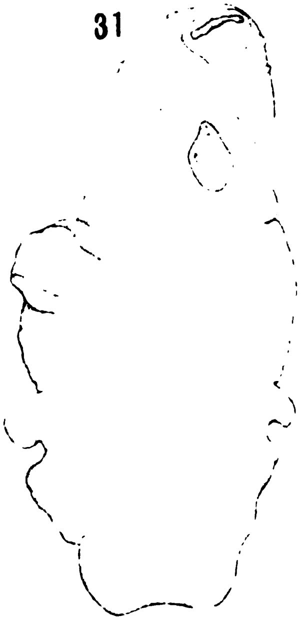

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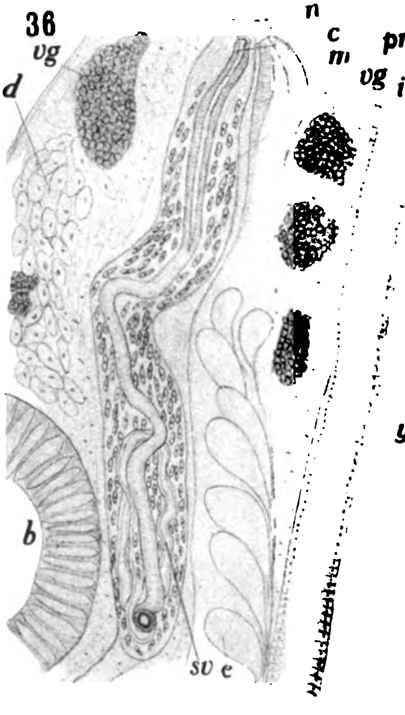

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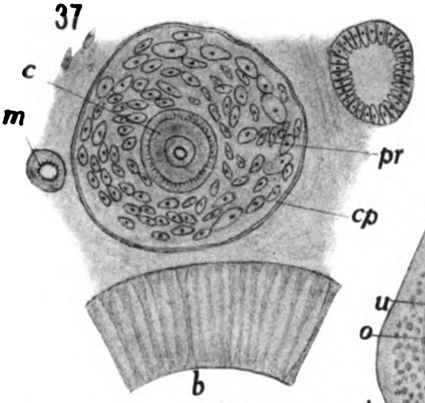

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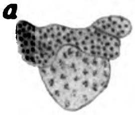

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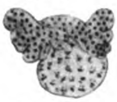

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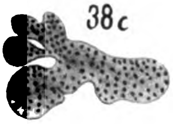

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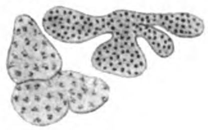

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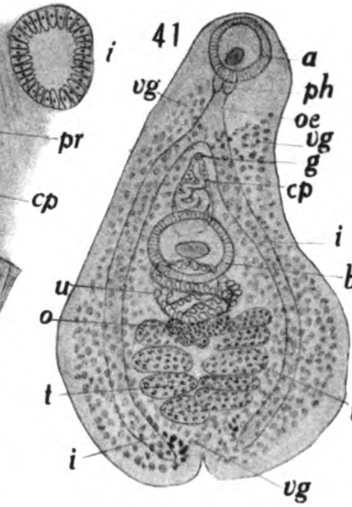

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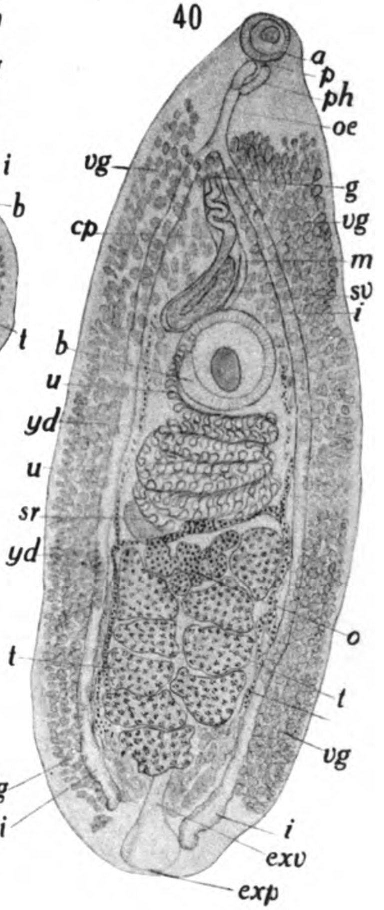

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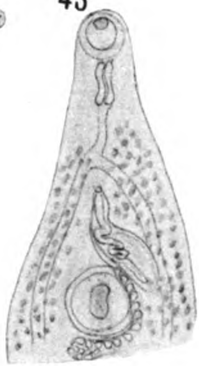

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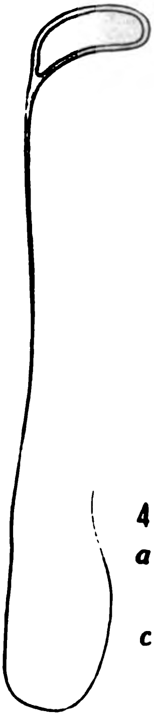

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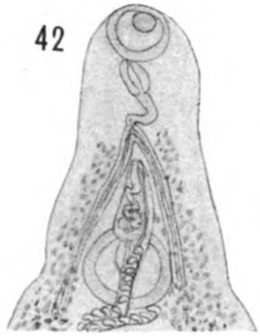

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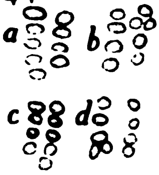

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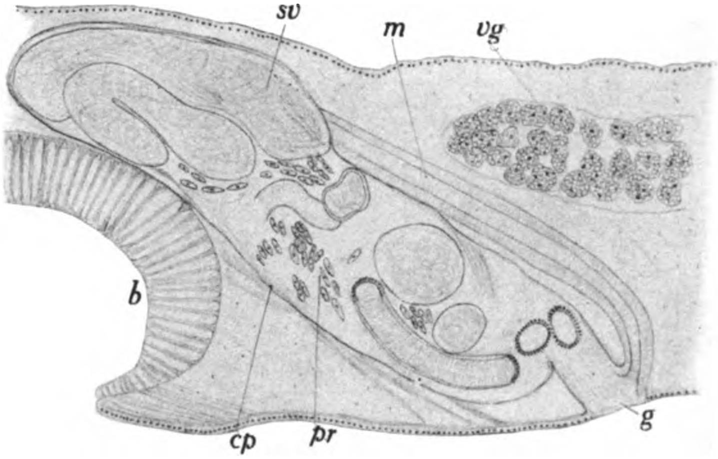

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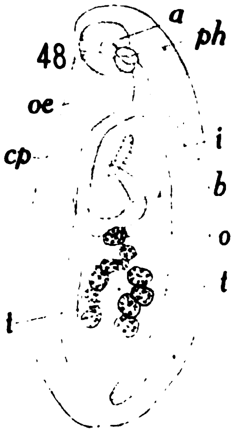

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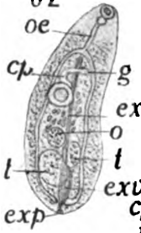

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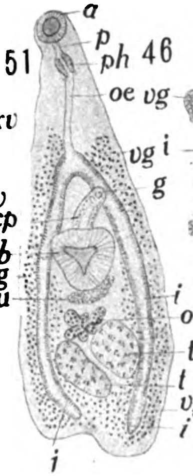

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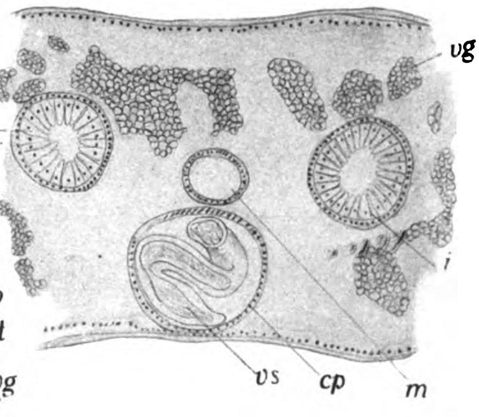

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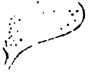

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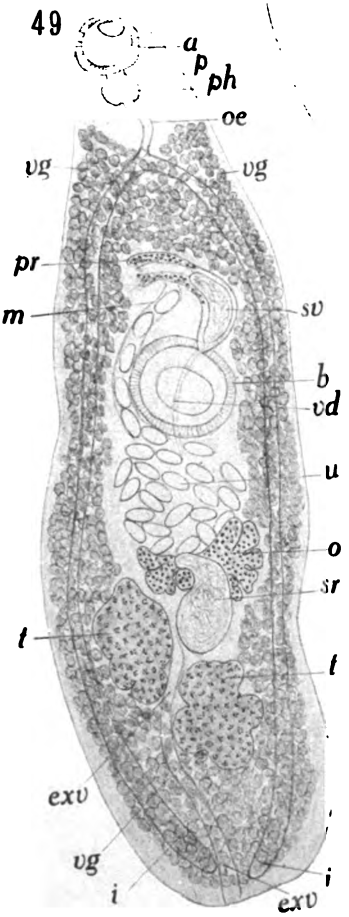

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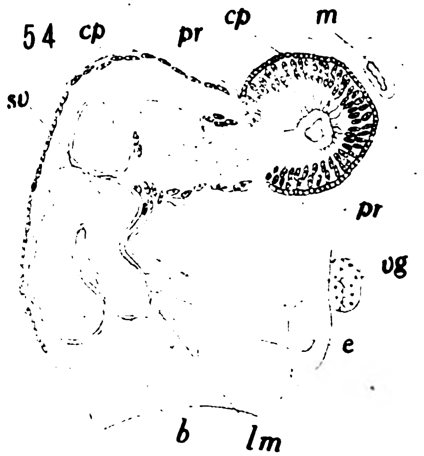

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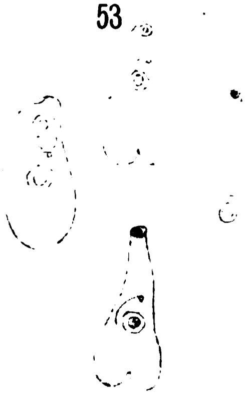

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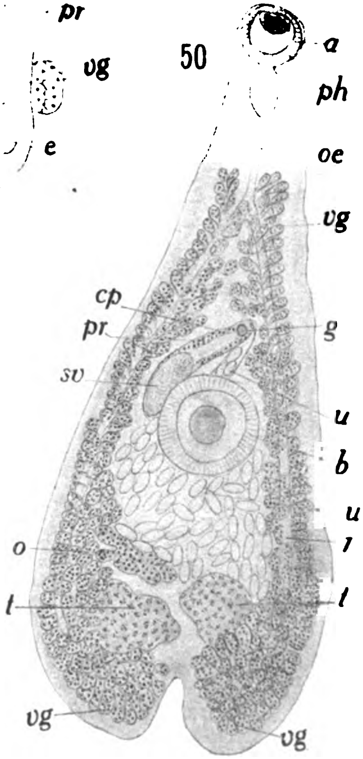

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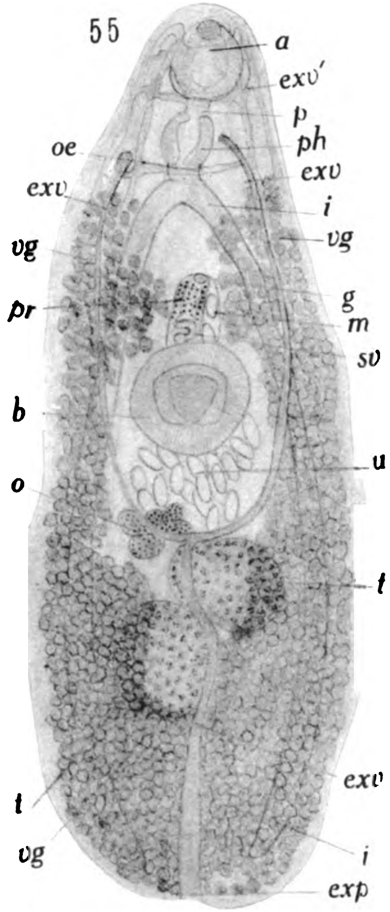

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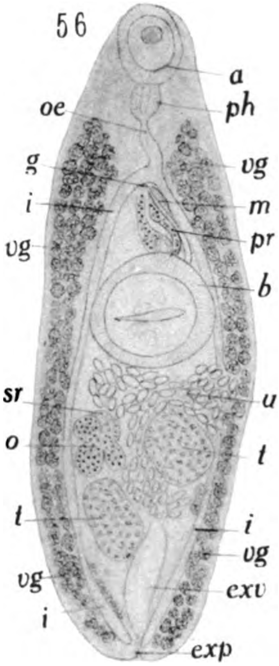

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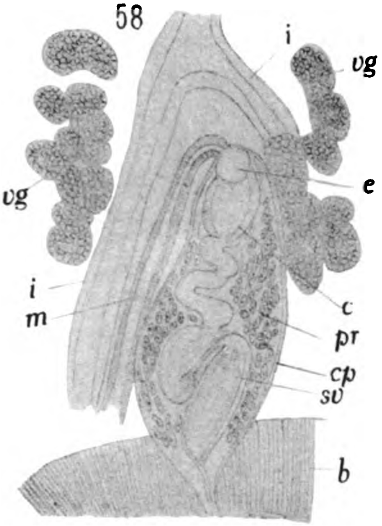

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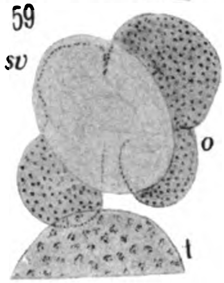

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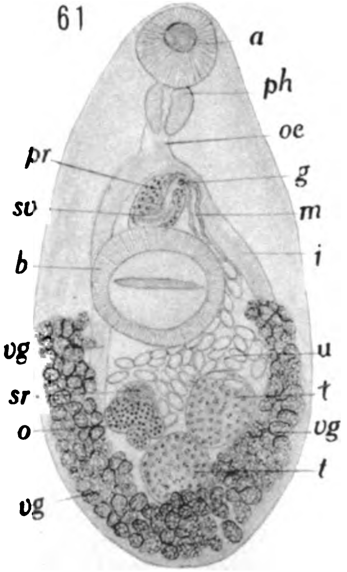

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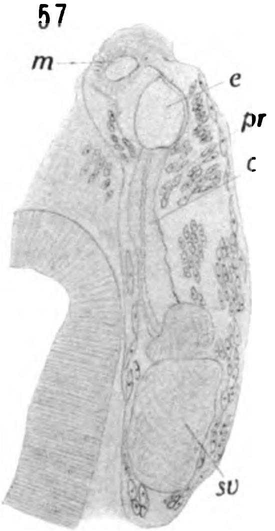

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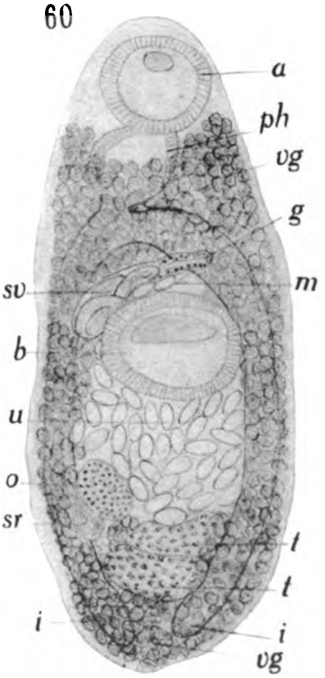

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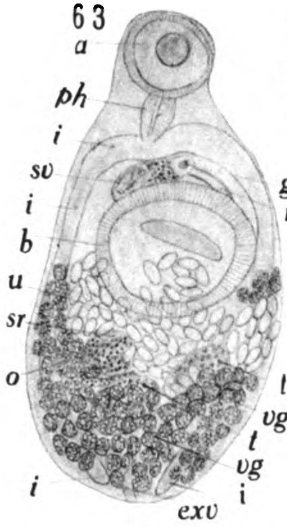

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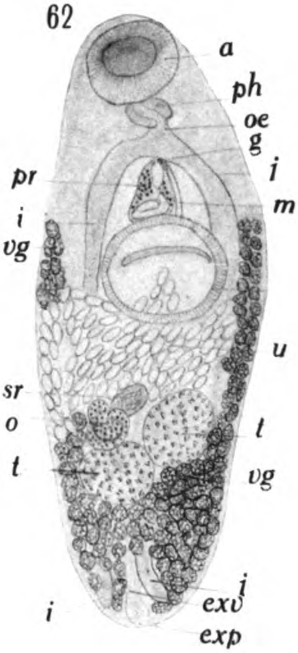

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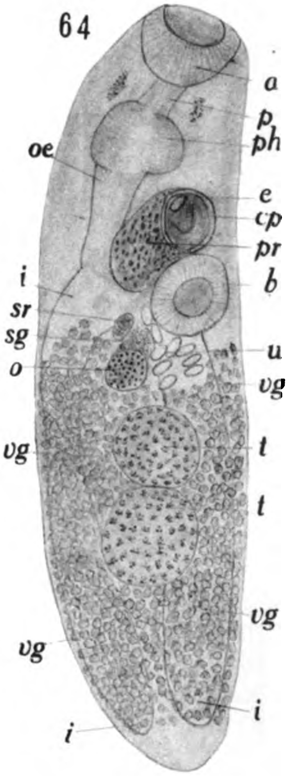

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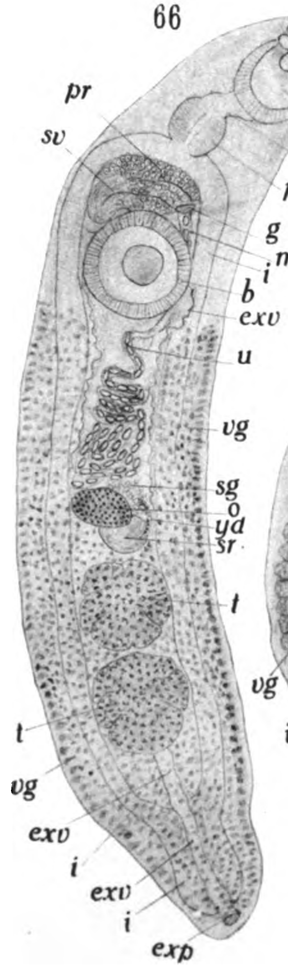

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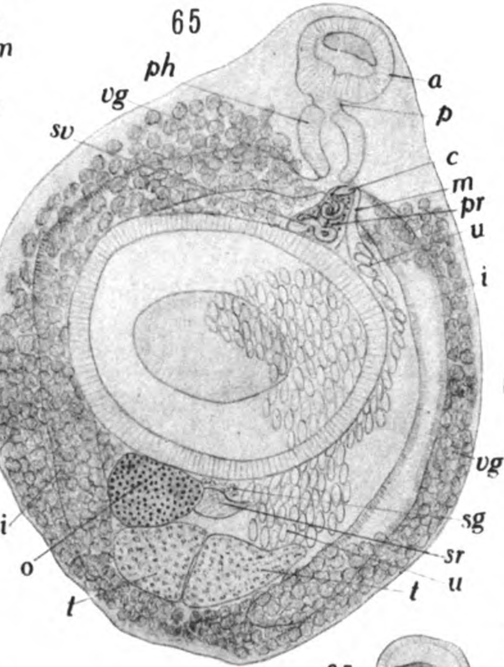

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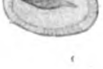

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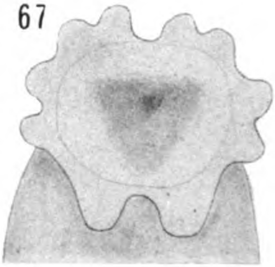

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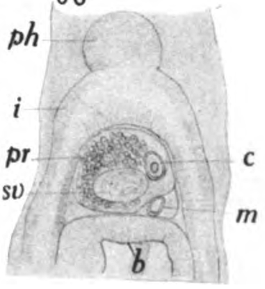

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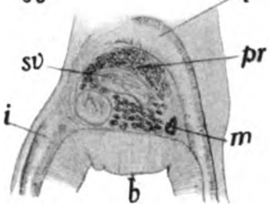

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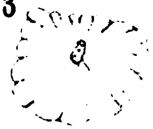

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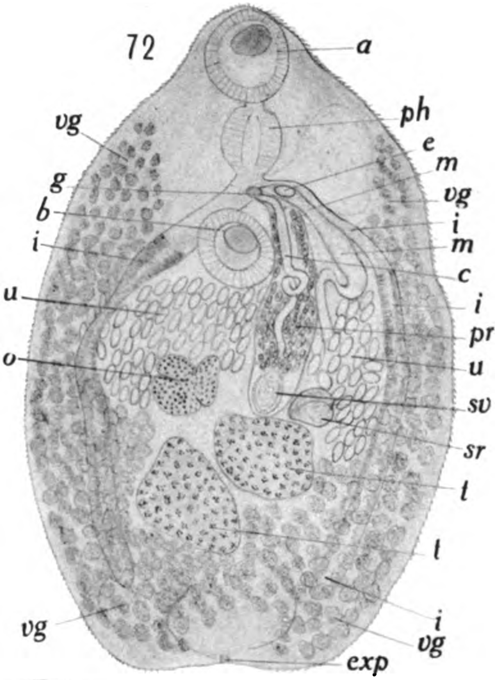

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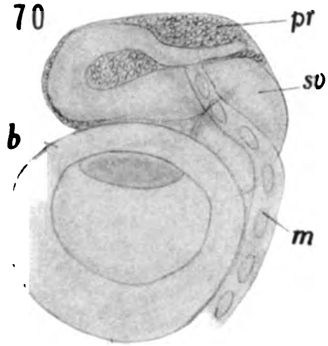

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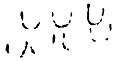

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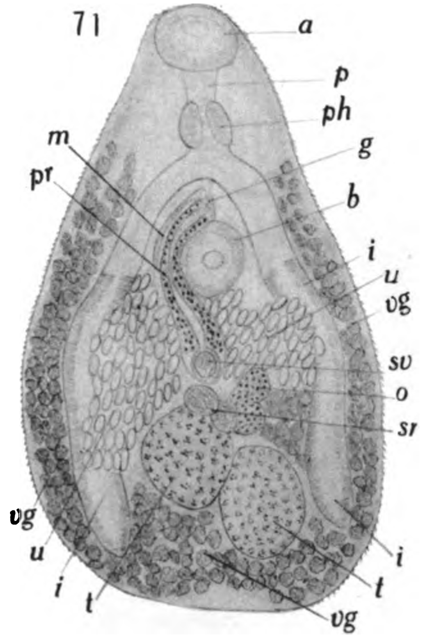

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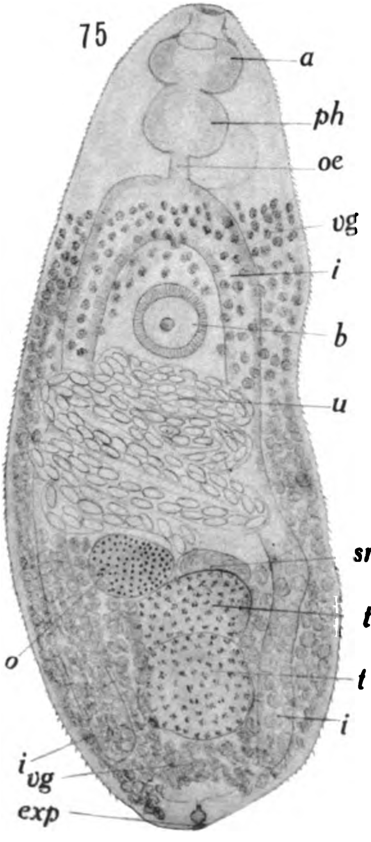

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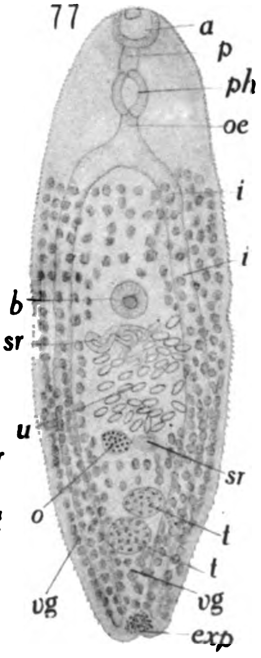

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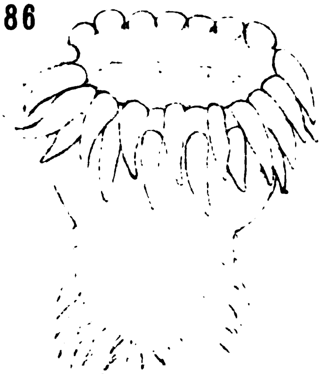

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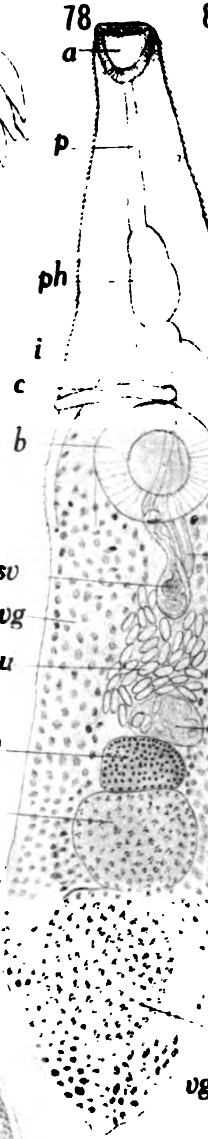

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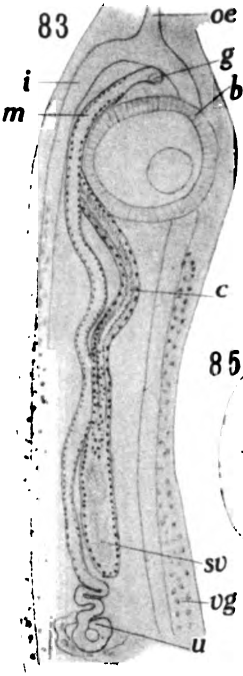

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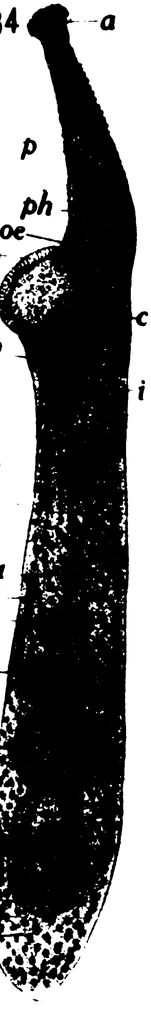

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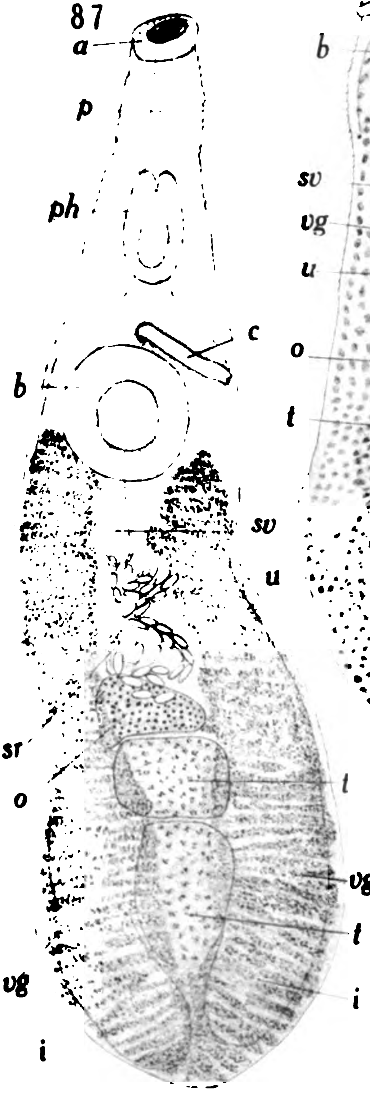

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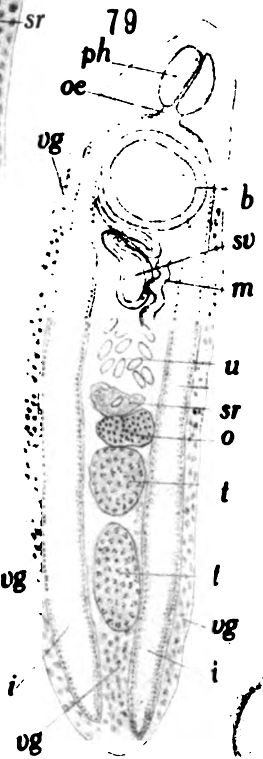

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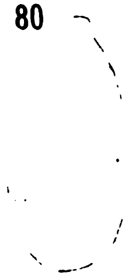

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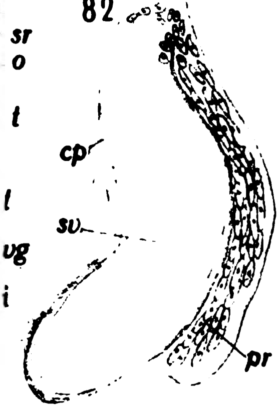

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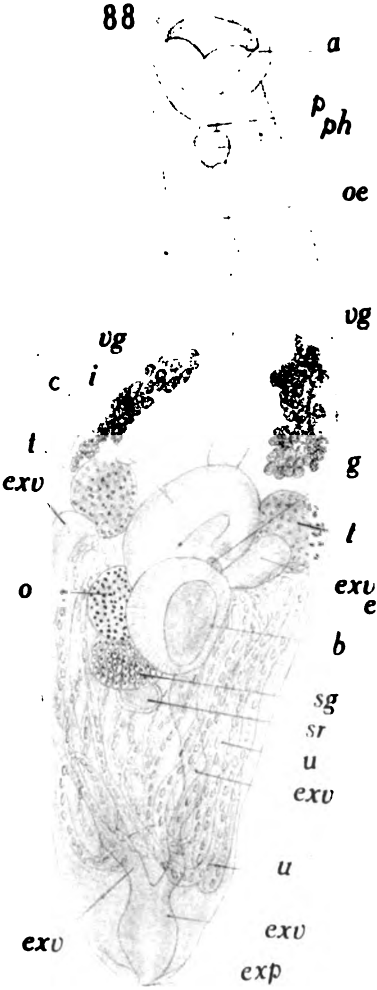

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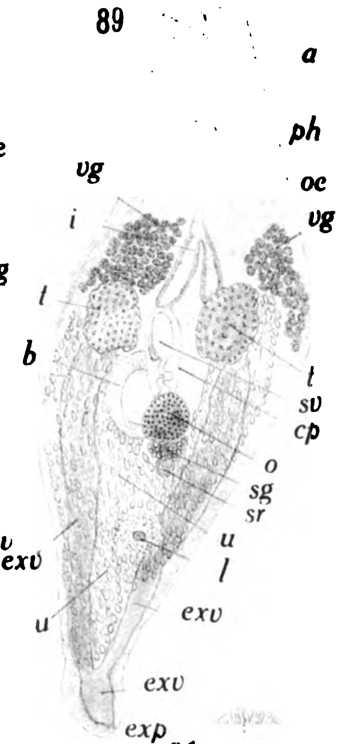

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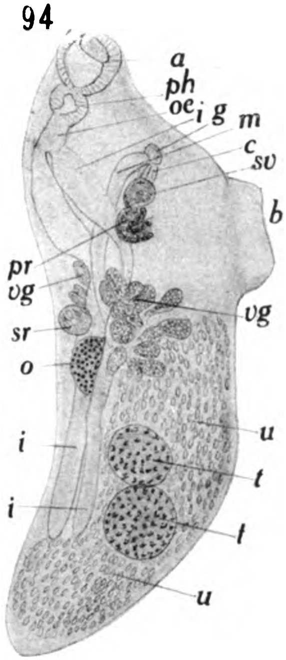

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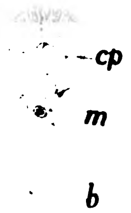

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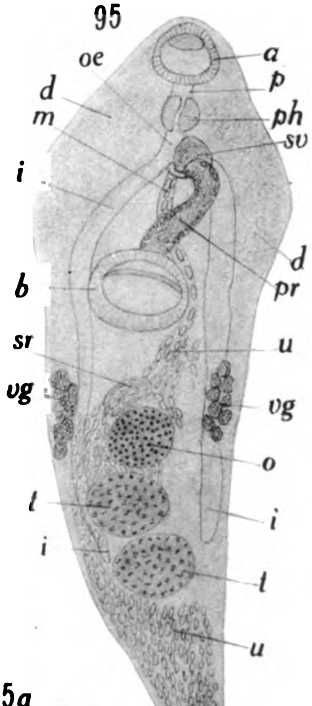

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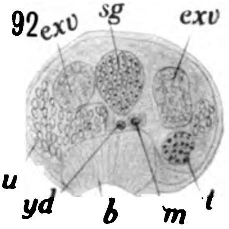

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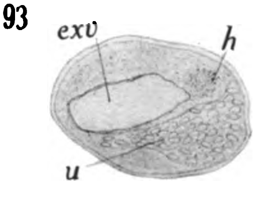

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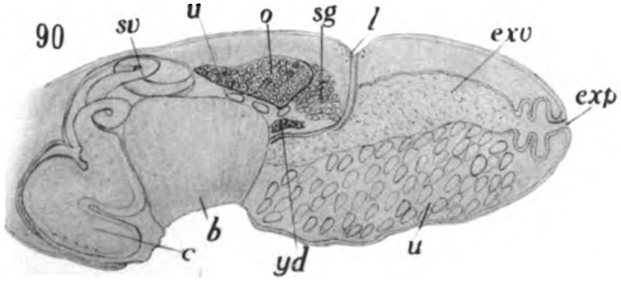

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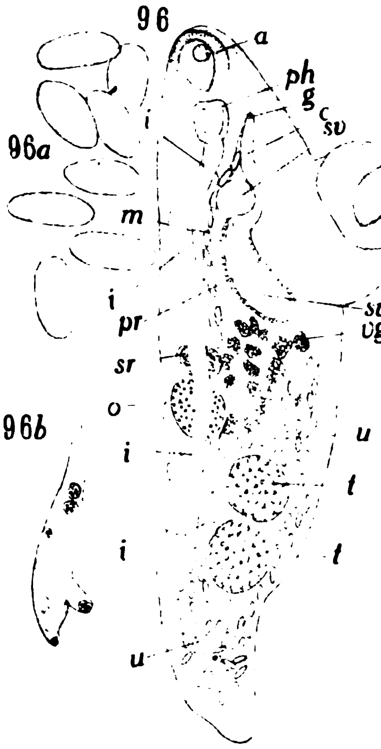

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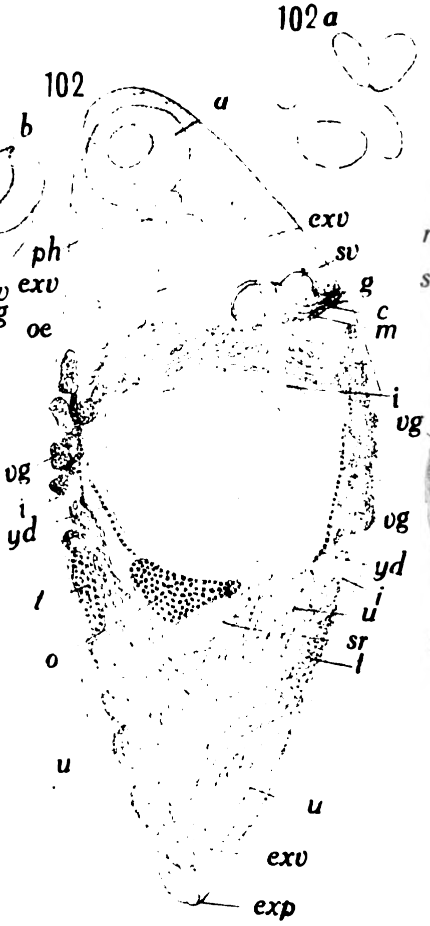

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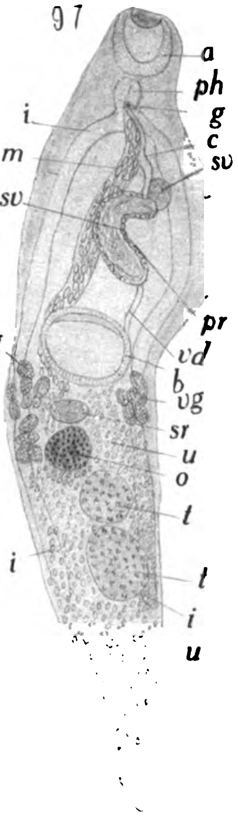

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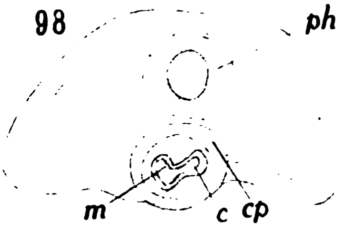

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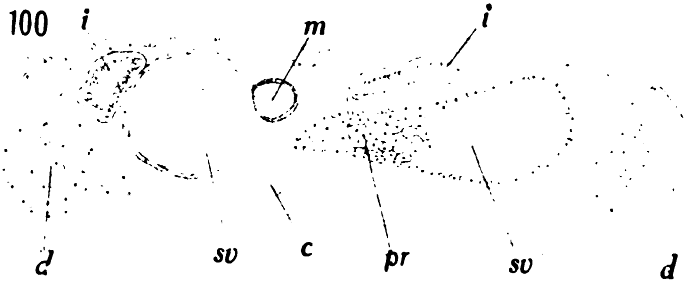

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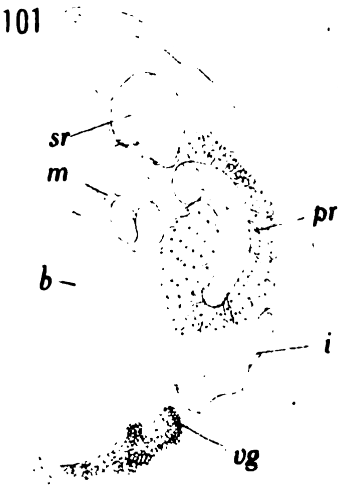

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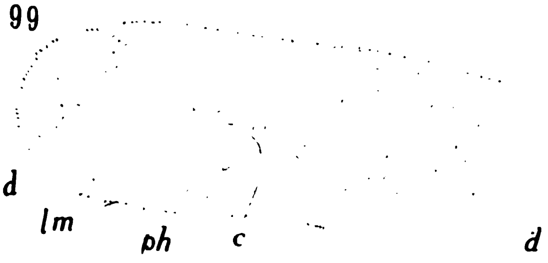

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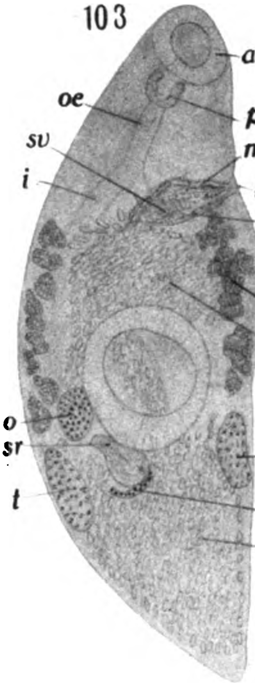

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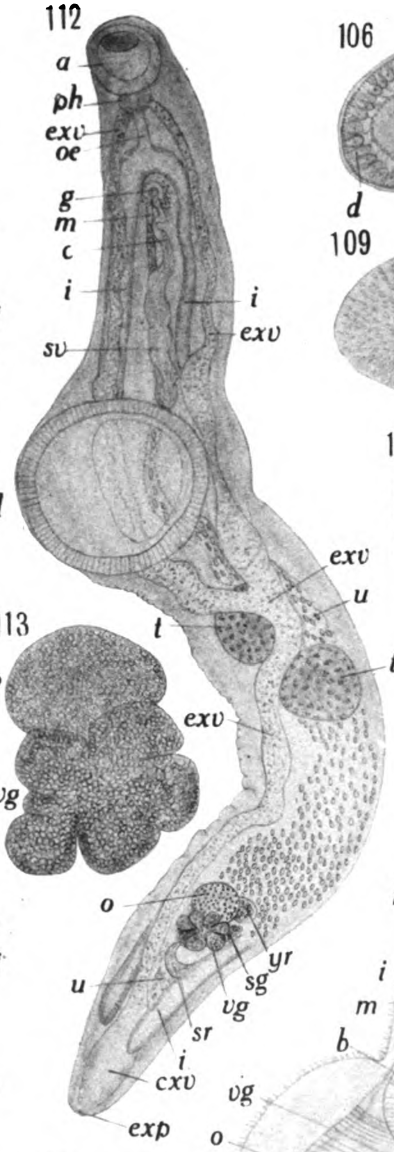

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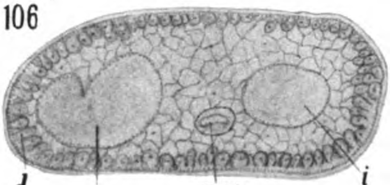

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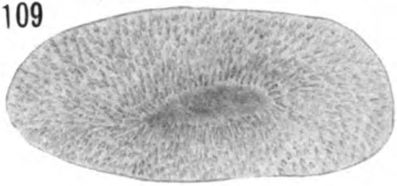

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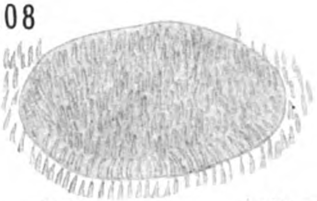

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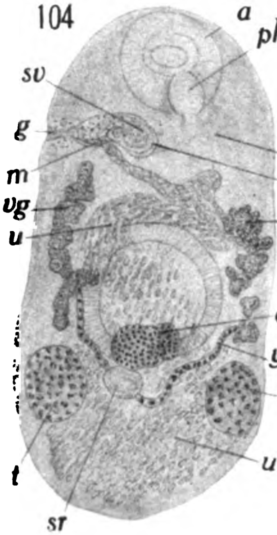

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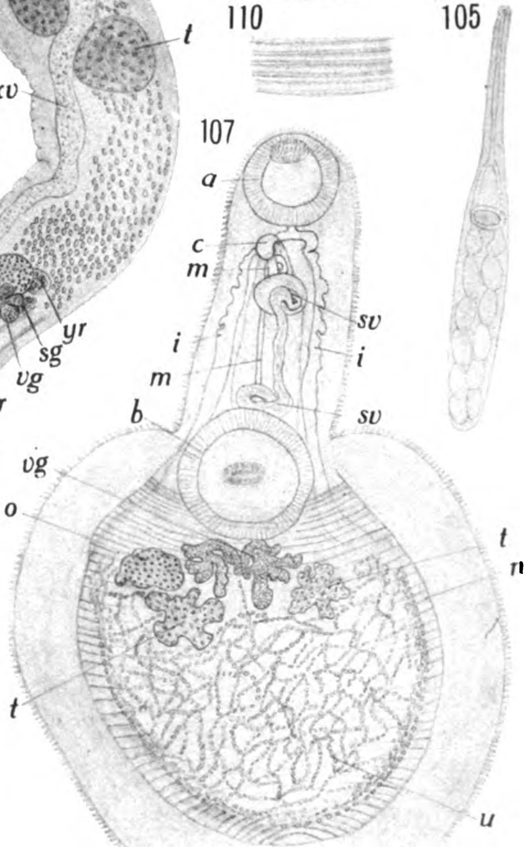

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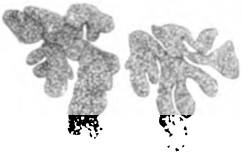

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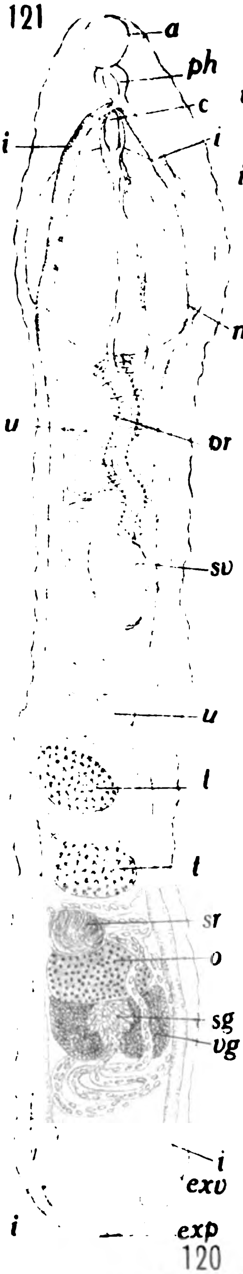

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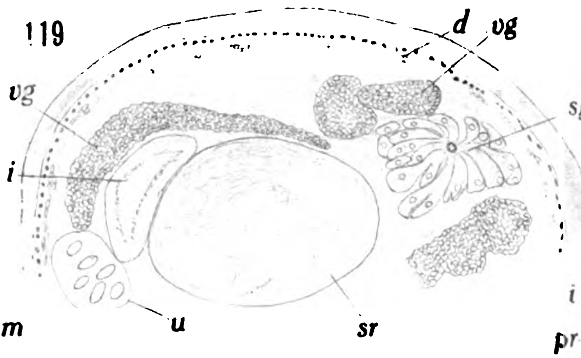

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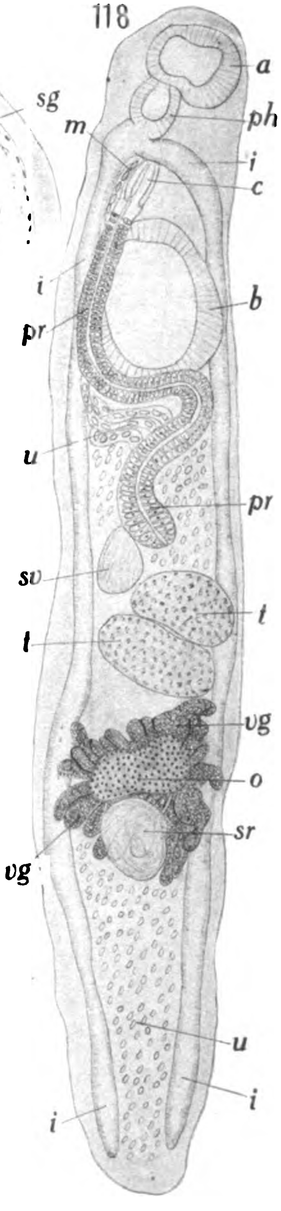

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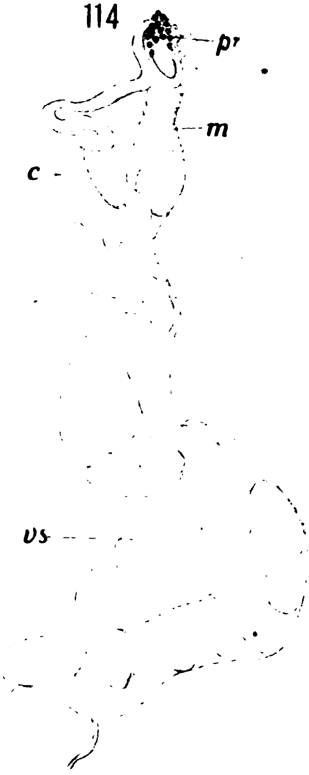

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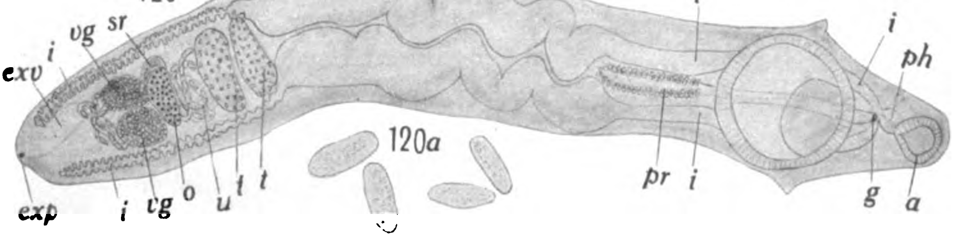

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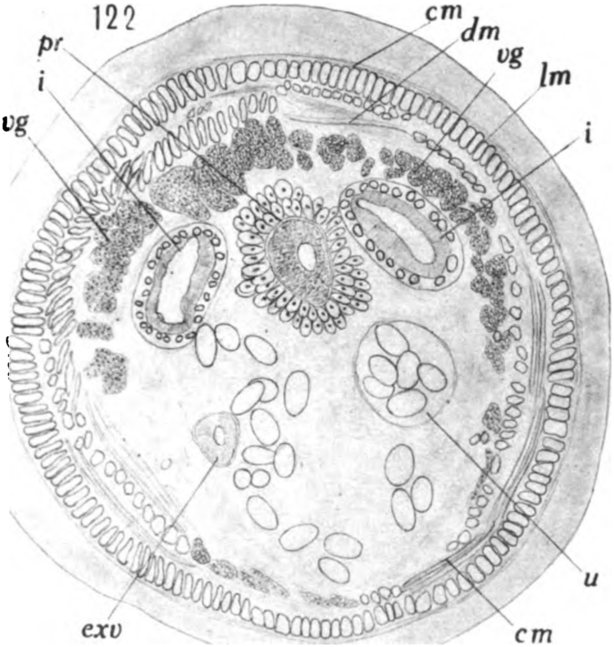

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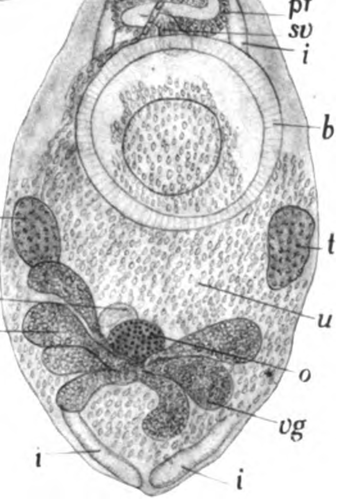

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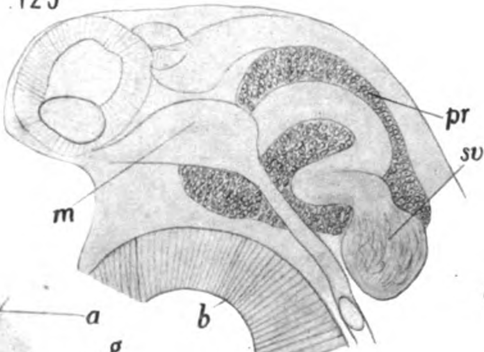

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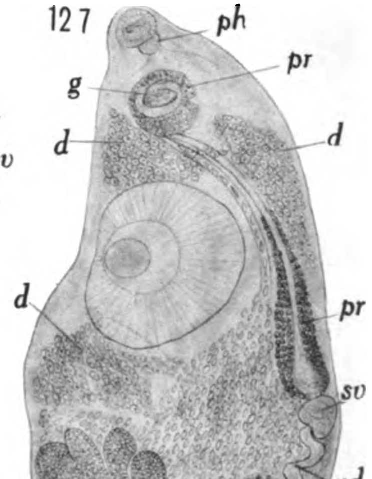

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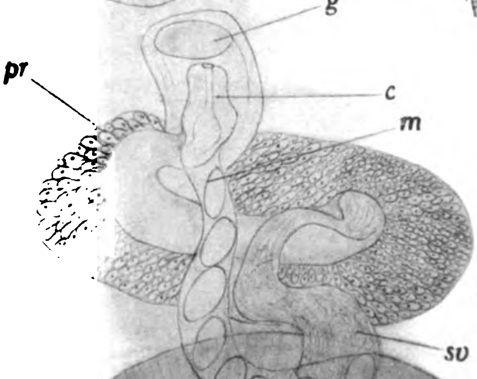

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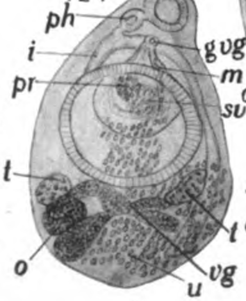

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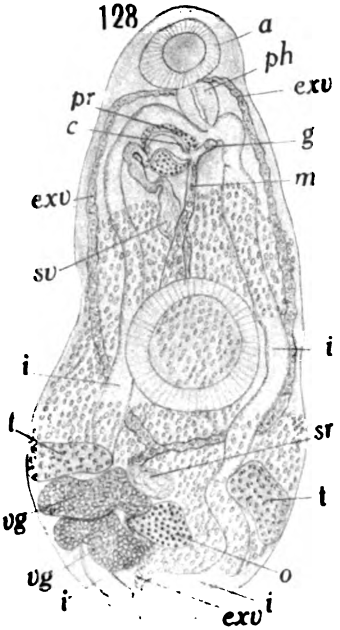

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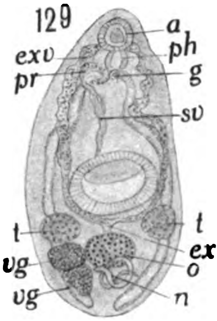

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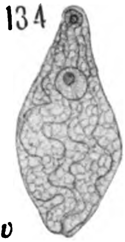

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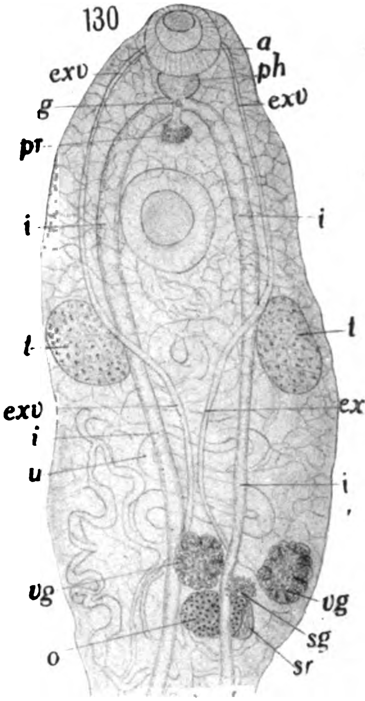

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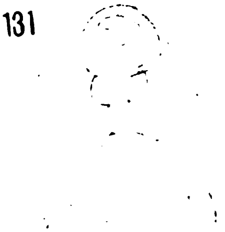

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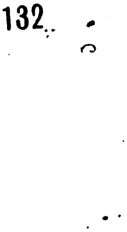

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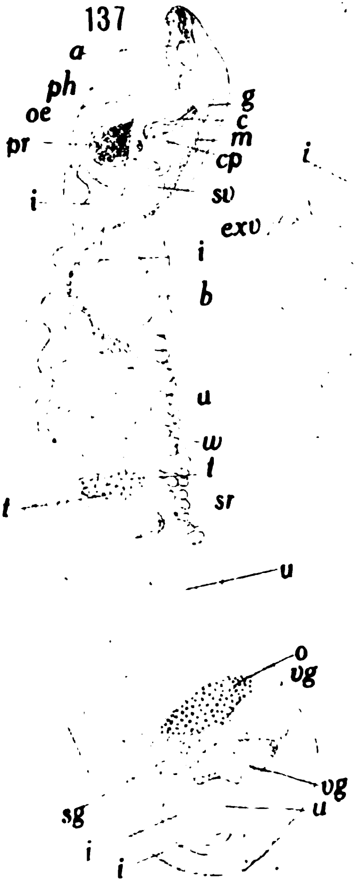

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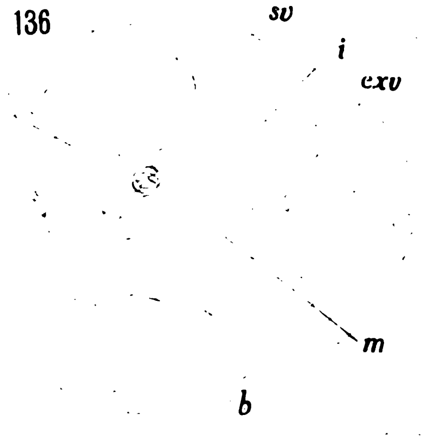

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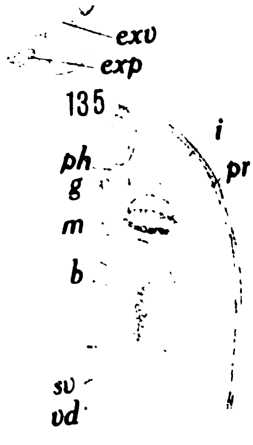

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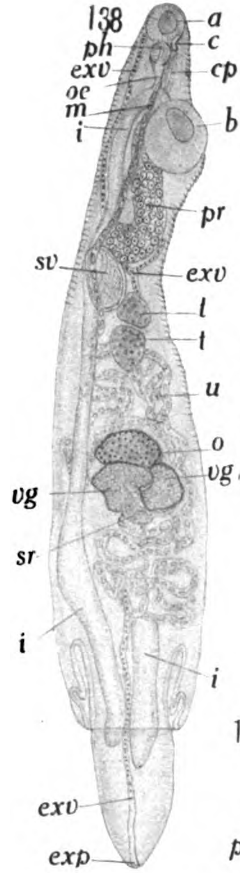

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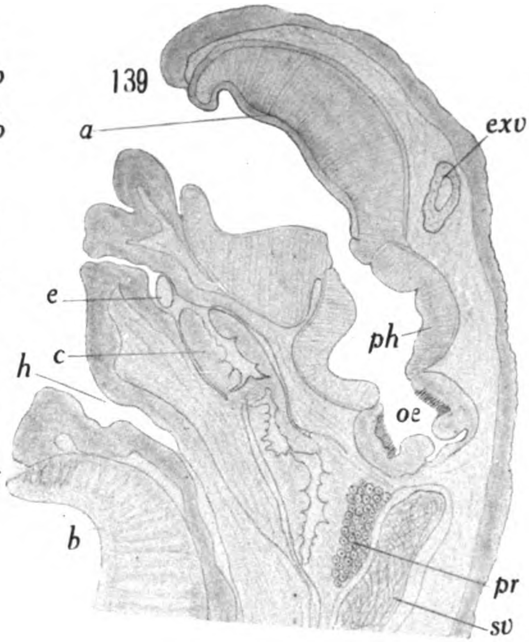

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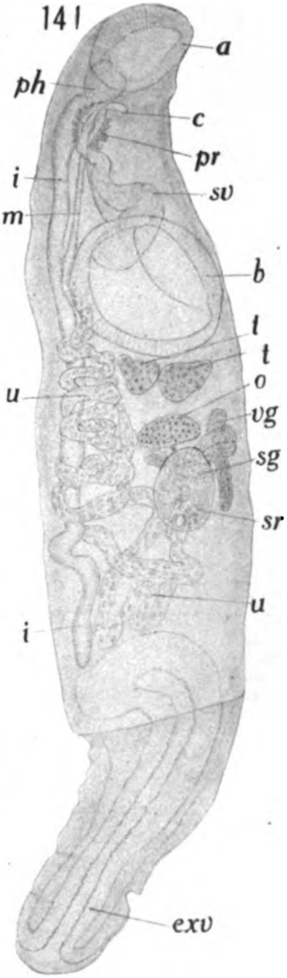

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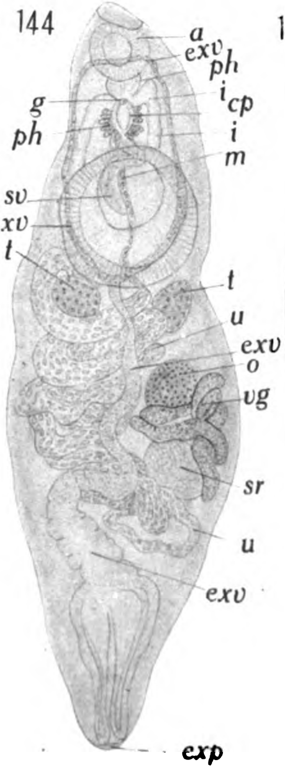

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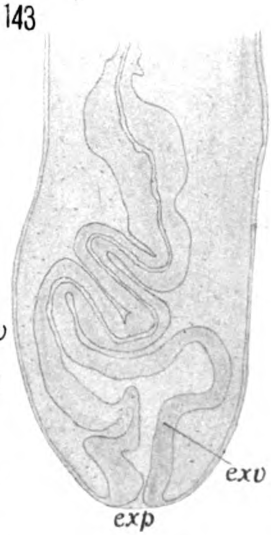

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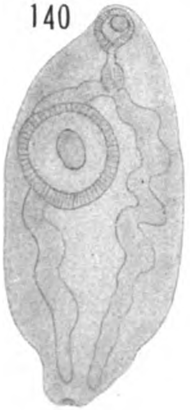

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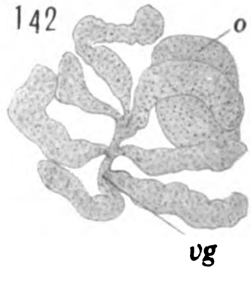

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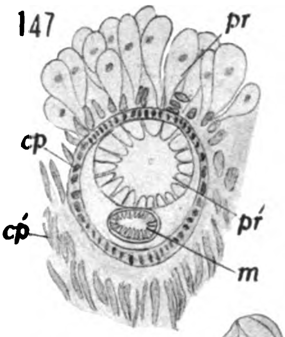

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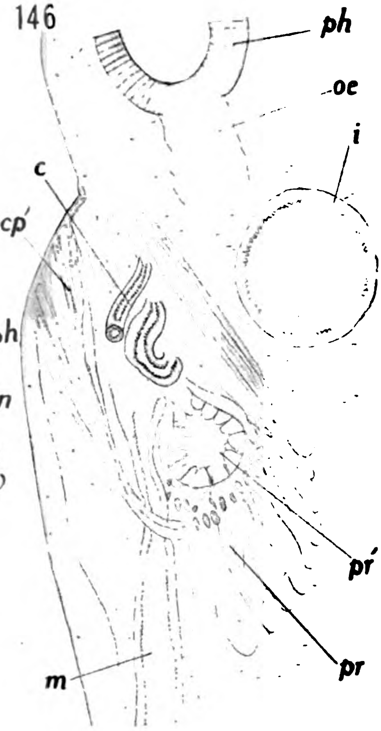

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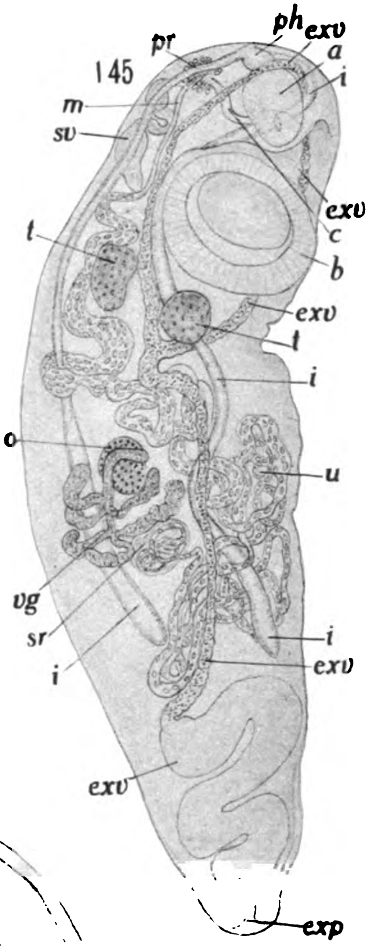

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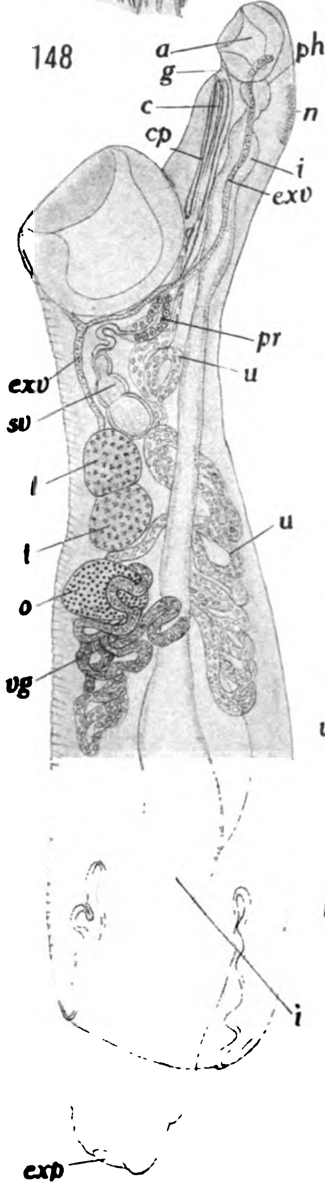

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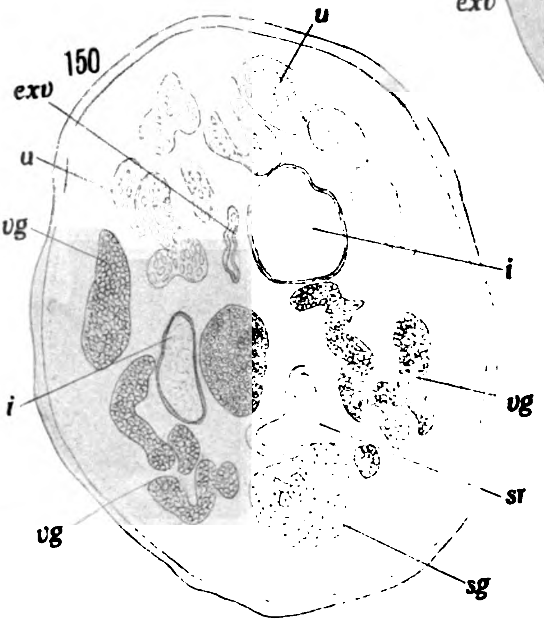

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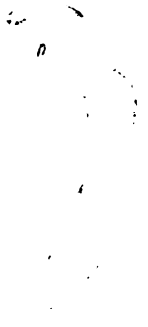

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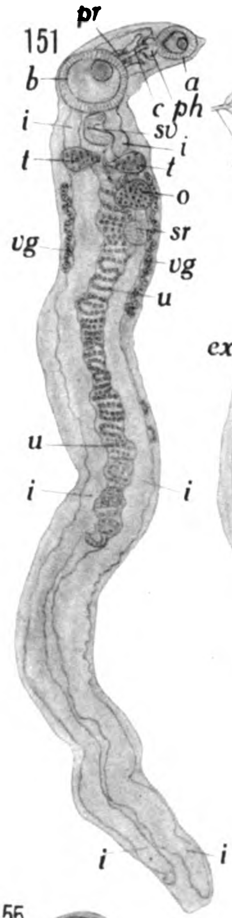

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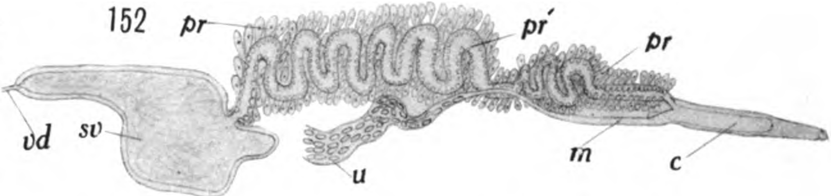

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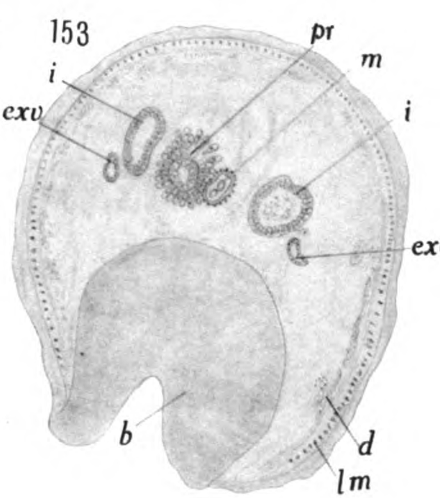

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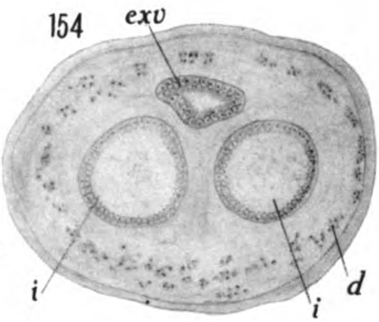

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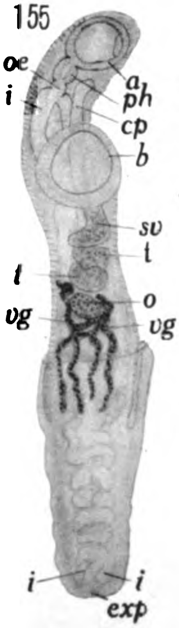

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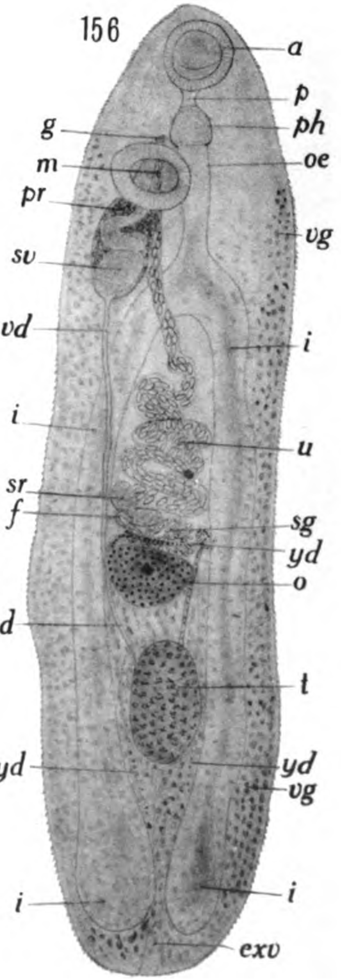

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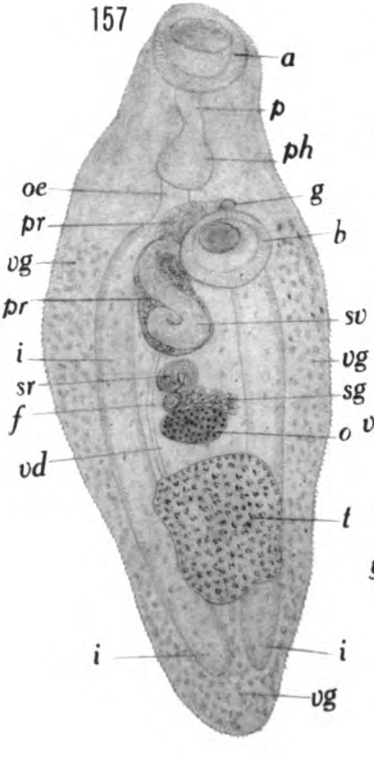

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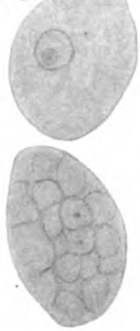

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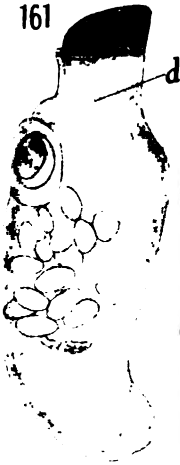

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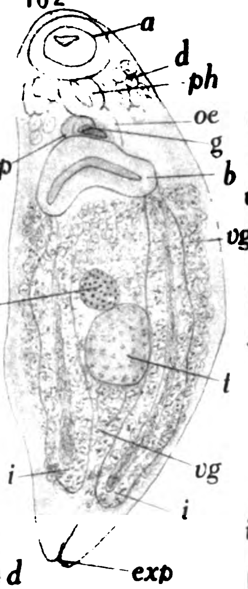

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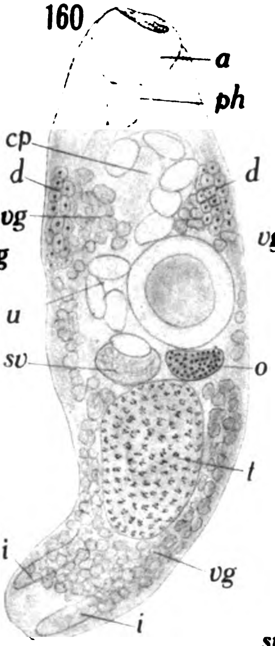

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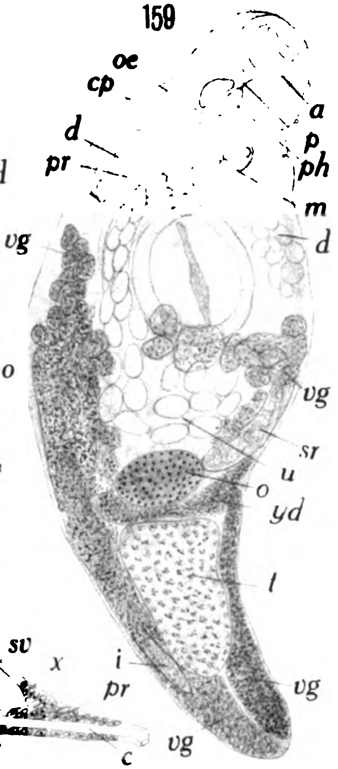

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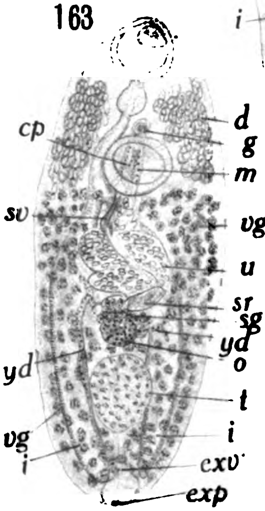

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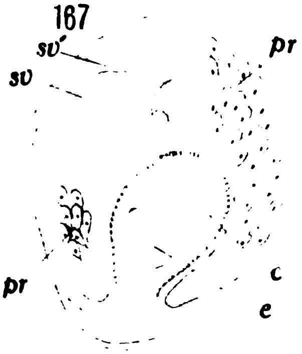

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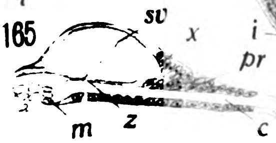

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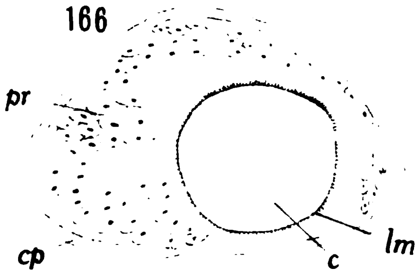

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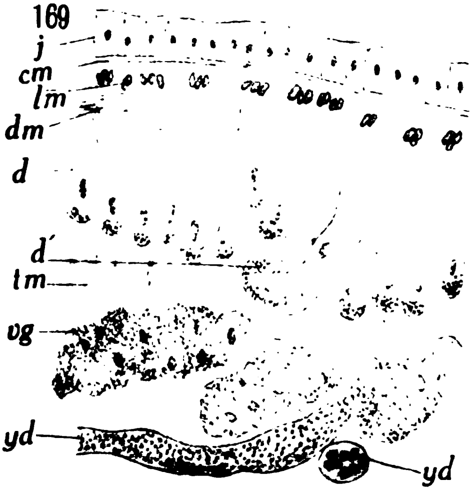

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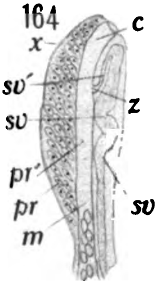

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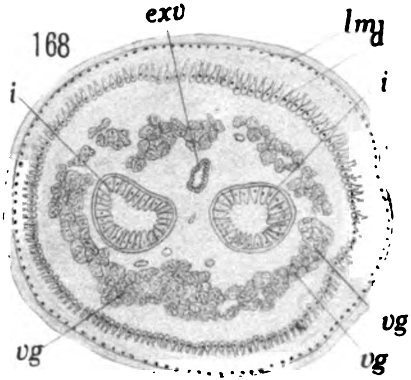

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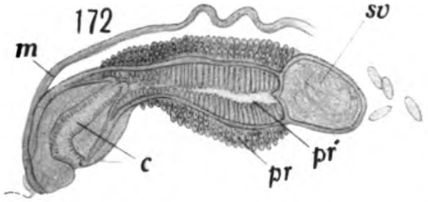

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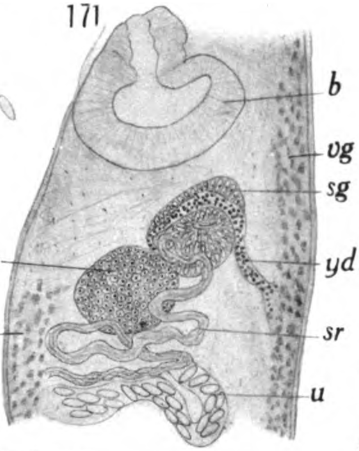

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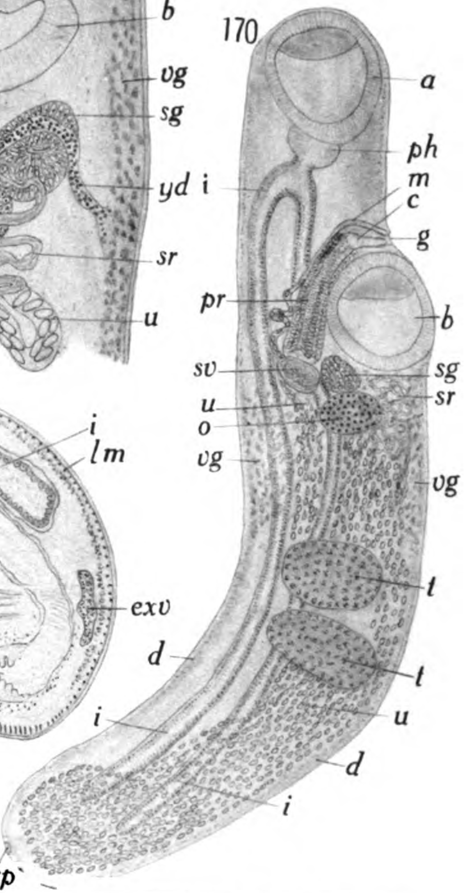

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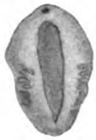

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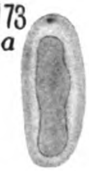

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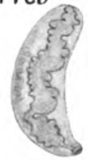

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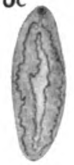

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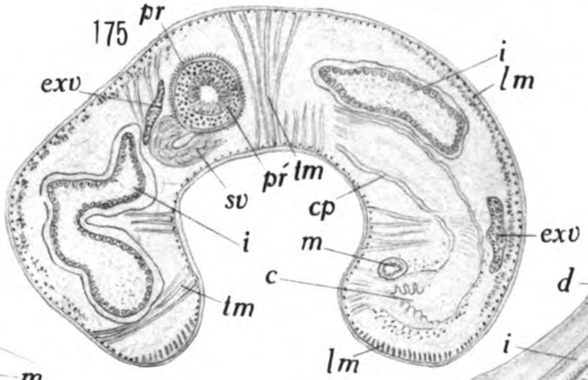

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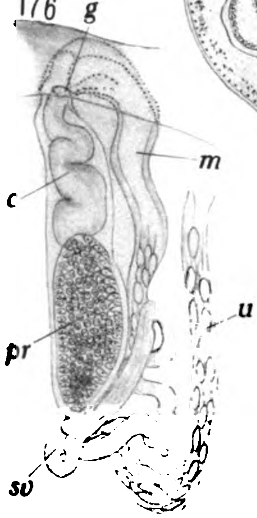

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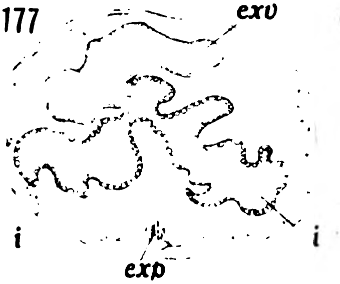

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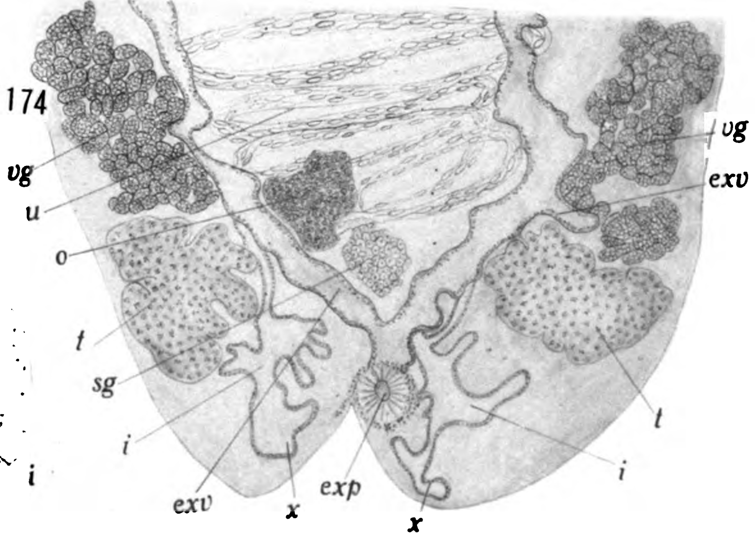

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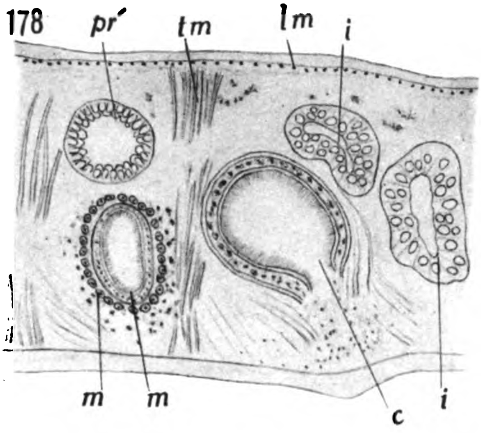

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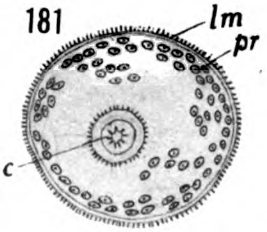

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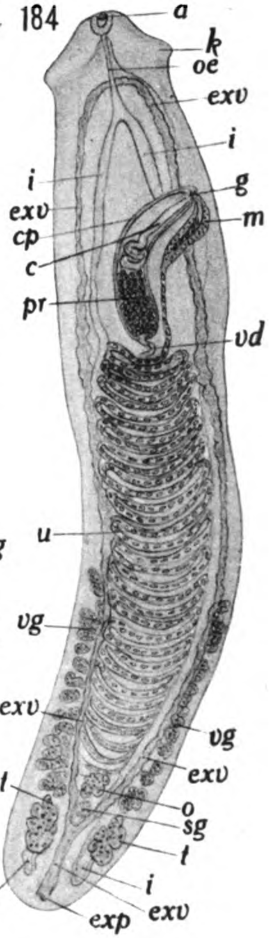

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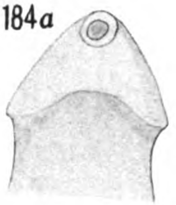

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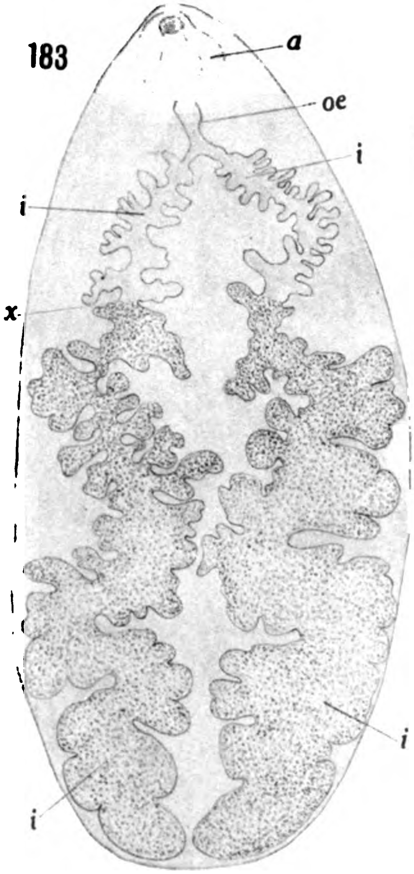

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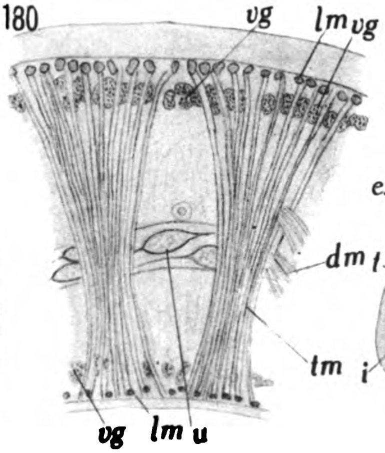

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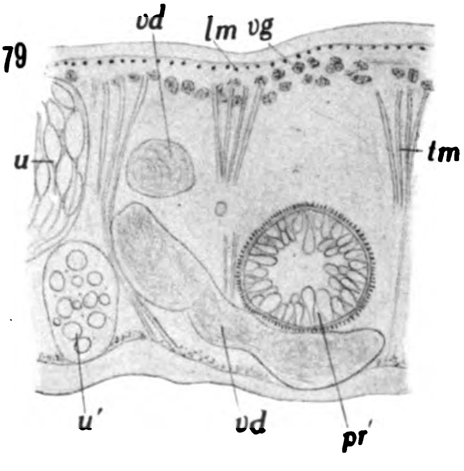

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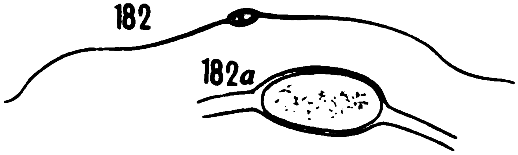

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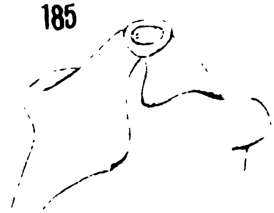

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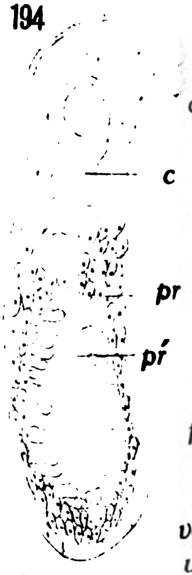

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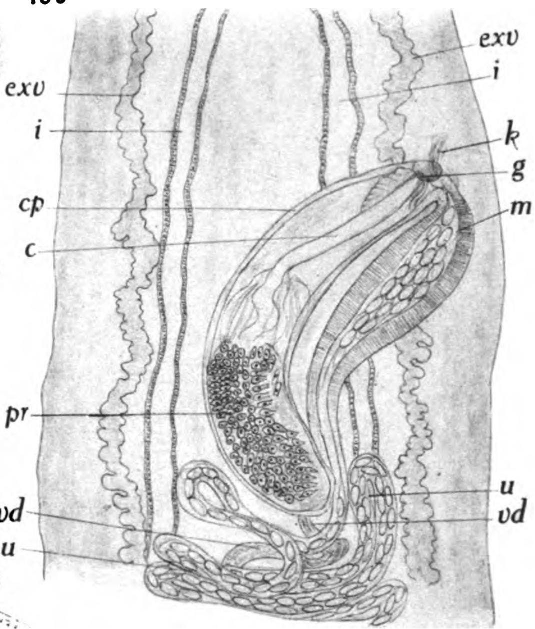

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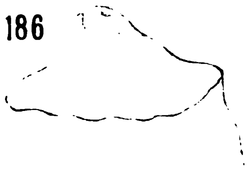

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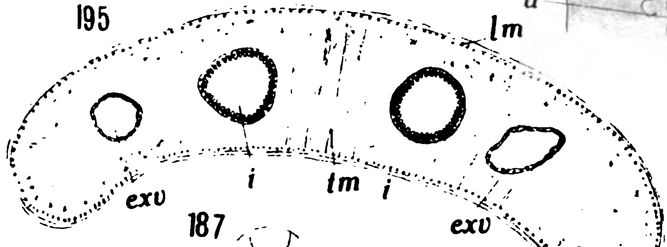

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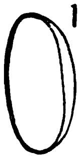

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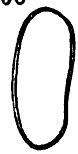

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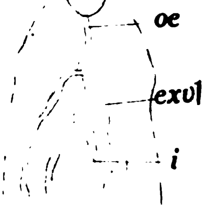

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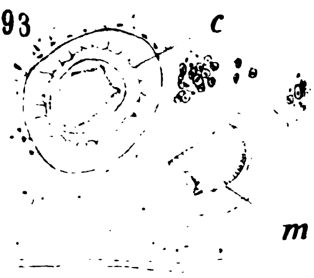

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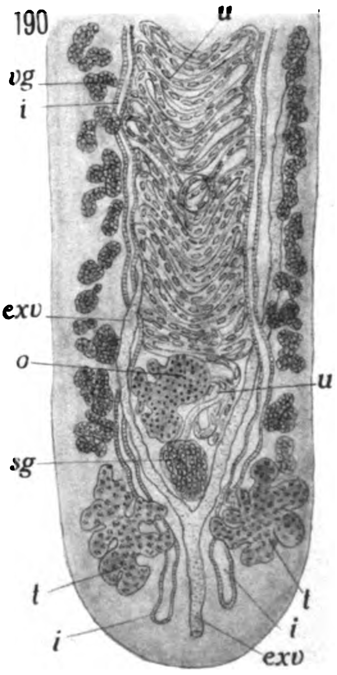

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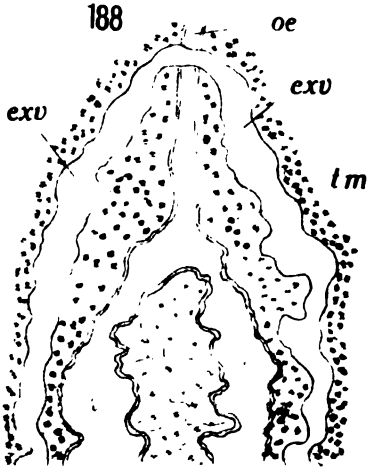

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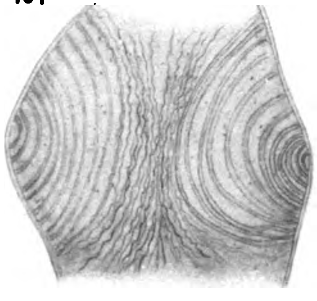

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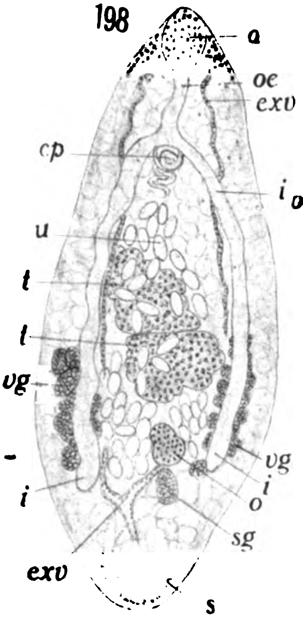

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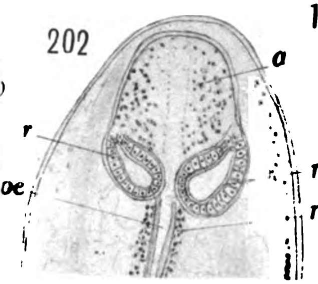

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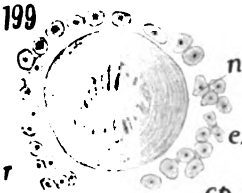

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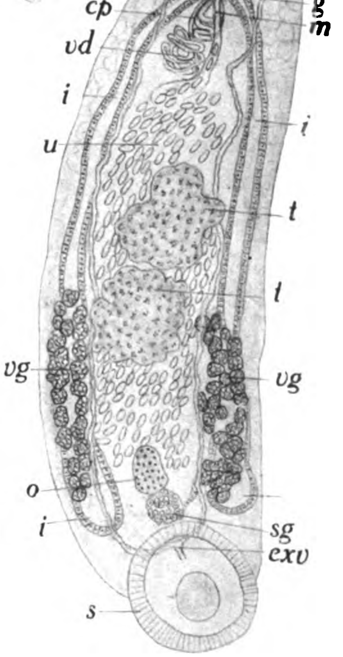

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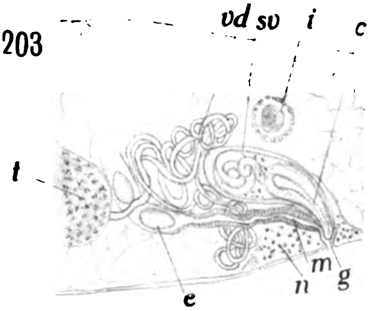

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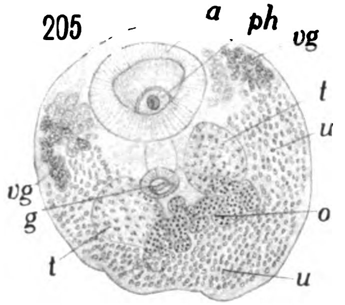

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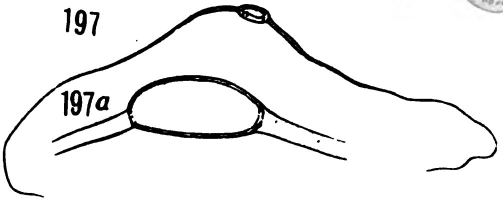

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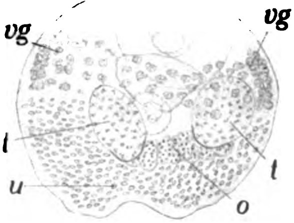

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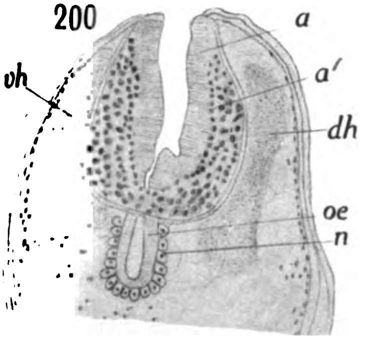

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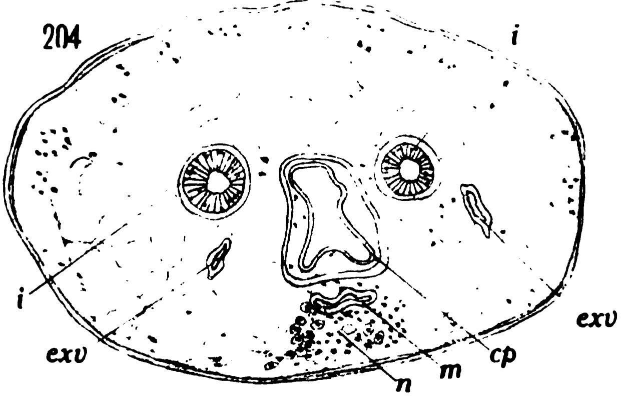

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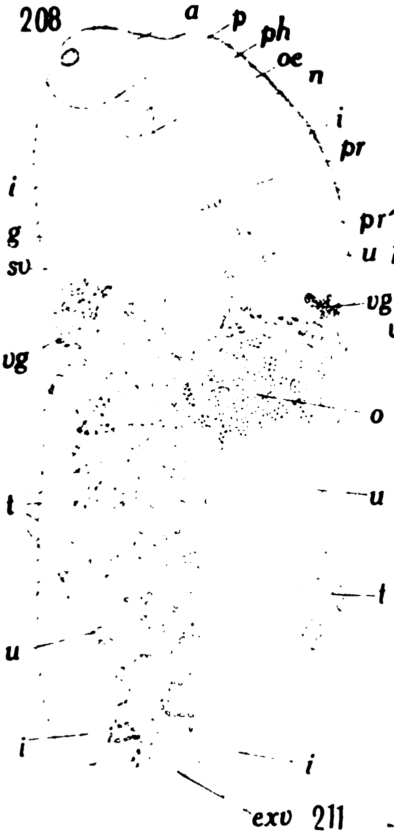

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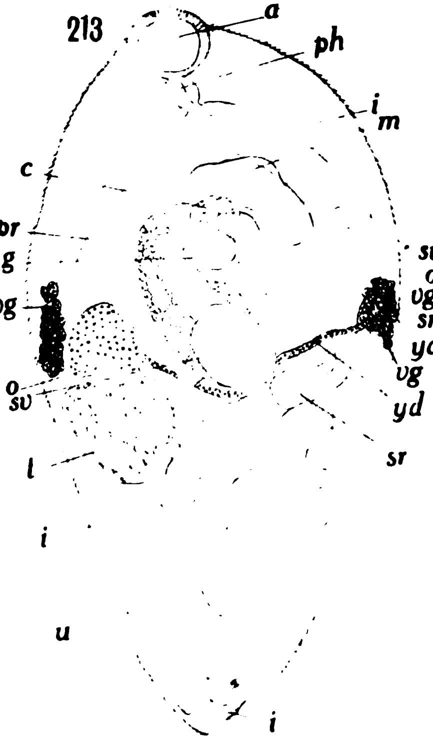

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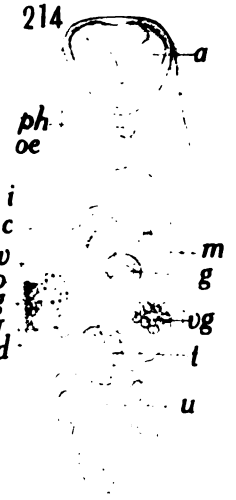

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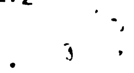

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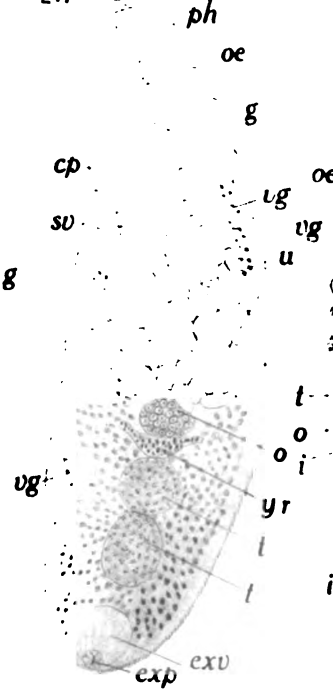

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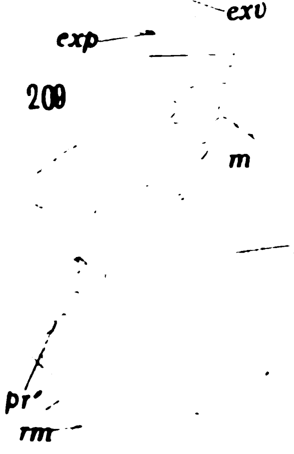

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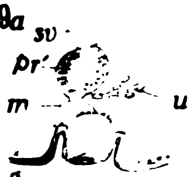

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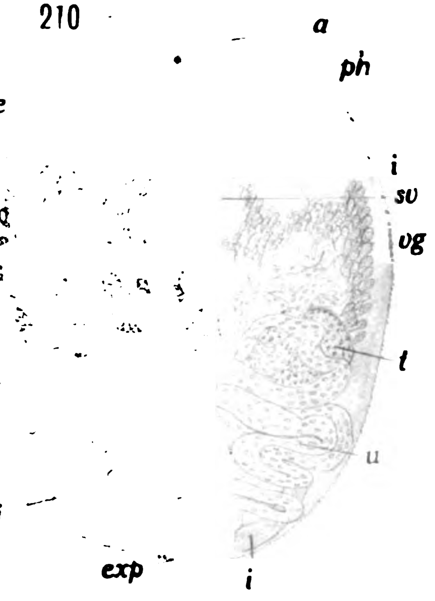

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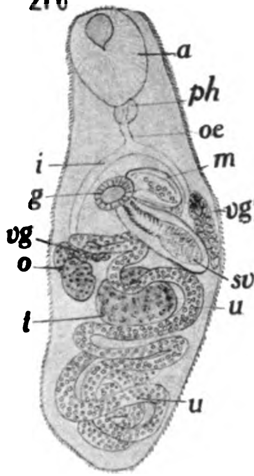

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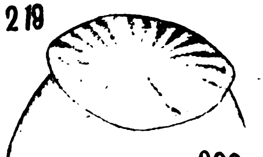

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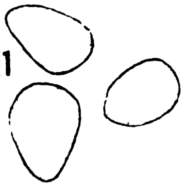

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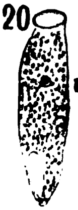

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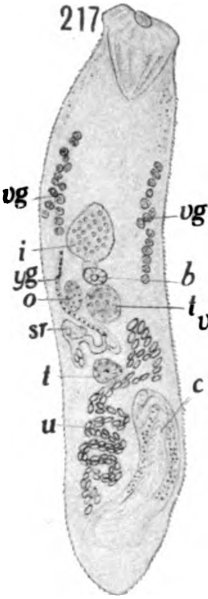

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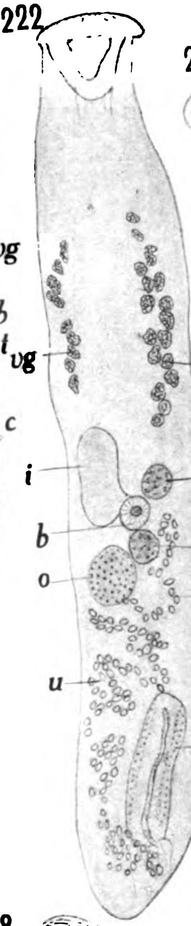

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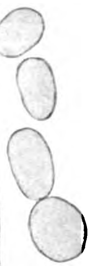

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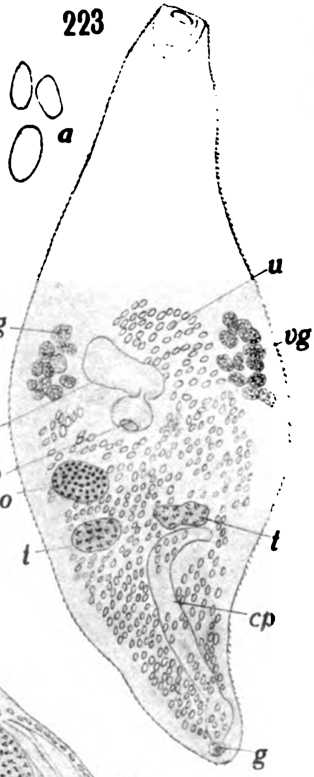

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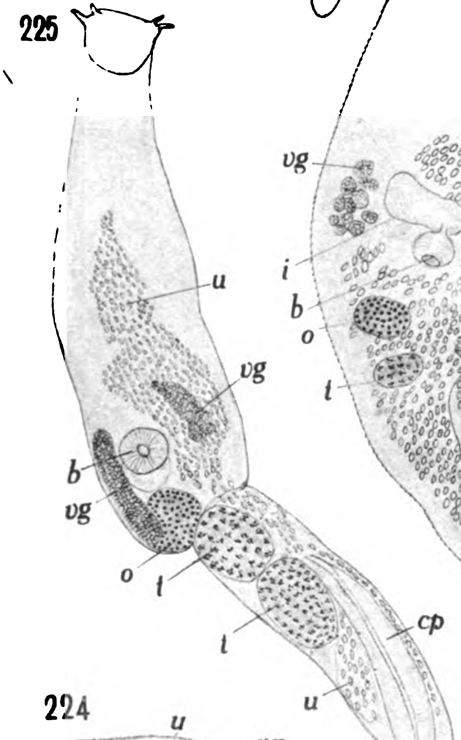

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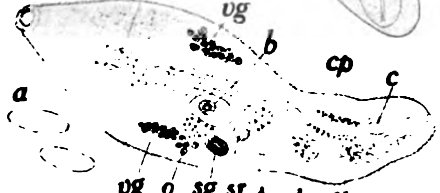

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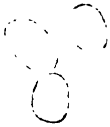

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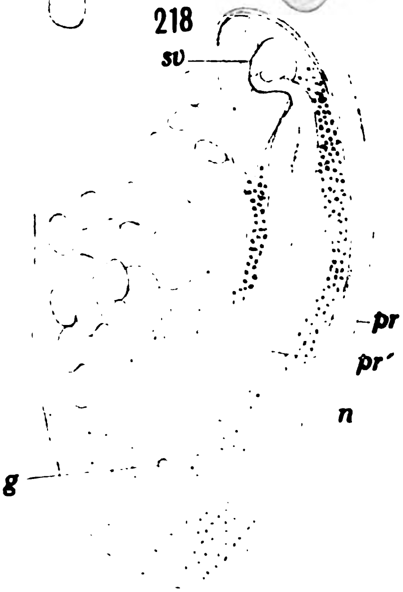

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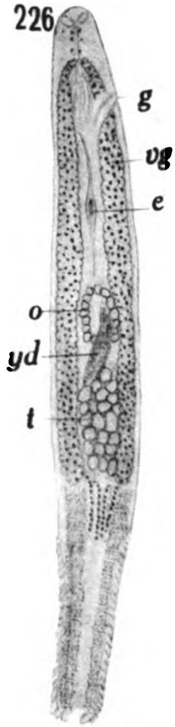

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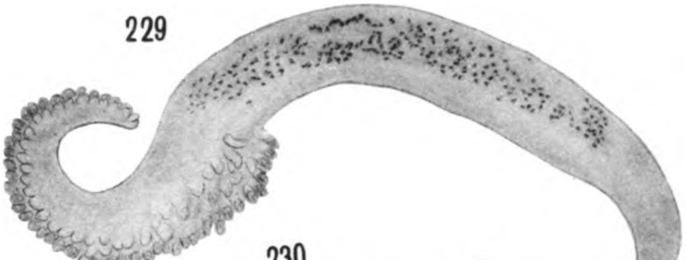

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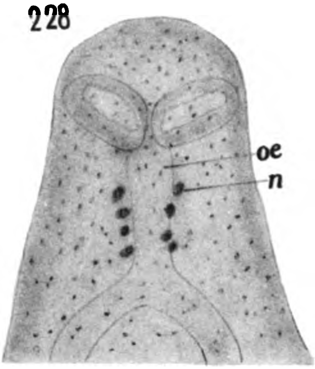

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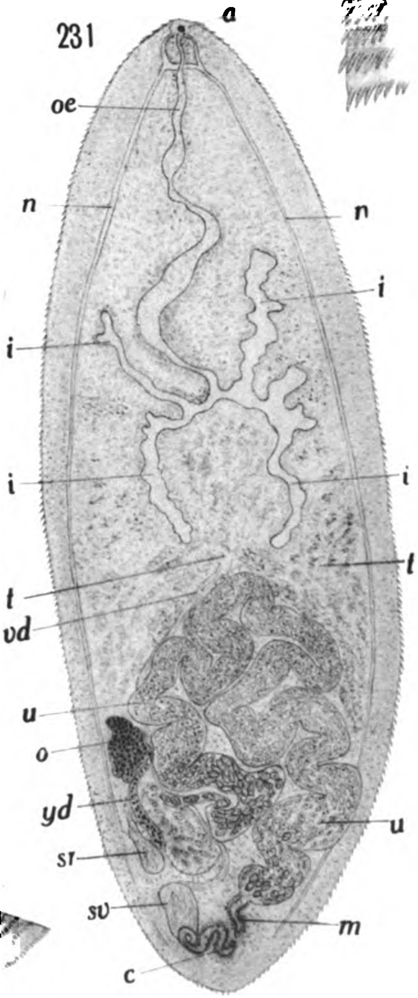

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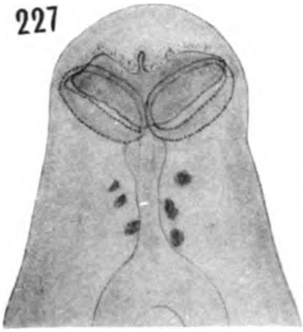

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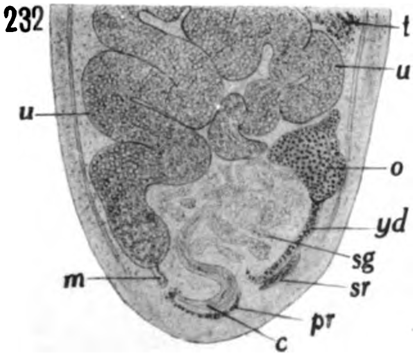

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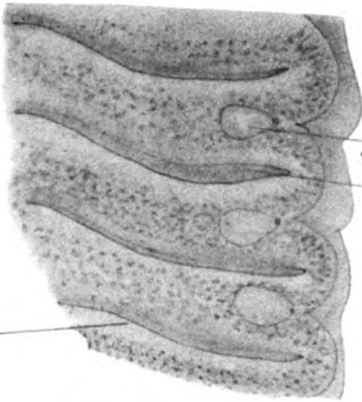

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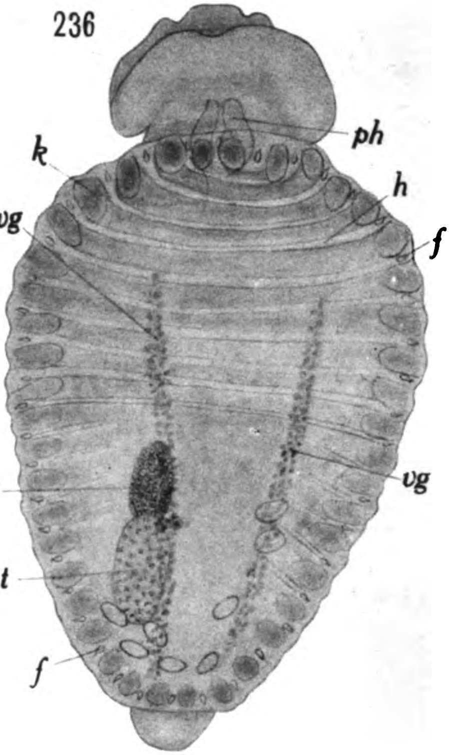

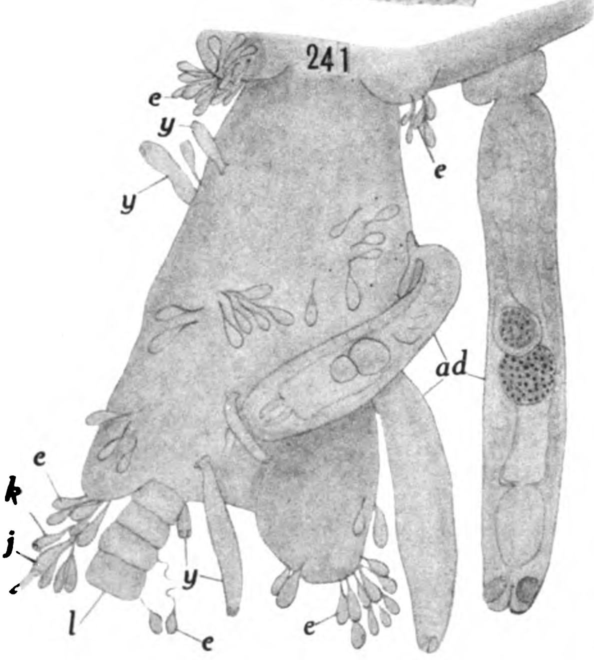

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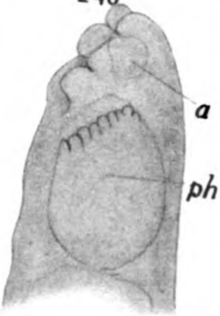

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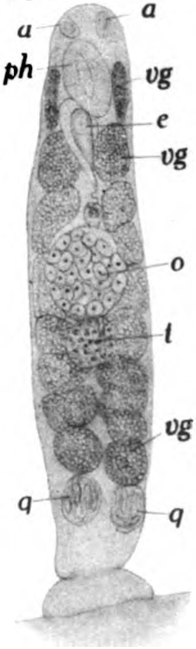

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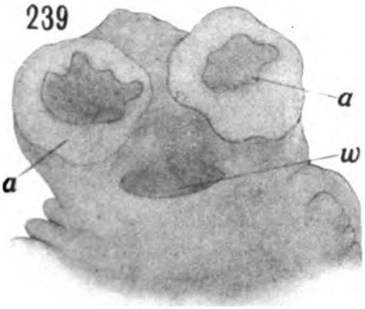

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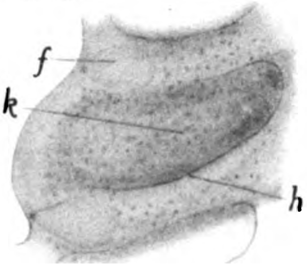

A CONTRIBUTION TO THE GEOLOGIC HISTORY OF THE FLORIDIAN PLATEAU.

BY THOMAS WAYLAND VAUGHAN,
Geologist in Charge of Coastal Plain Investigation, U. S. Geological Survey,
Custodian of Madreporaria, U. S. National Museum.

15 plates, 6 text figures.

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A CONTRIBUTION TO THE GEOLOGIC HISTORY OF THE FLORIDIAN PLATEAU.

By Thomas Wayland Vaughan.

INTRODUCTION.

This paper is the outgrowth of my association with two organizations, the United States Geological Survey and the Carnegie Institution of Washington. As Geologist in charge of Coastal Plain Investigations of the former organization, I have had unusual opportunities to familiarize myself with the geology of Florida, supplementing my previous field work in the State by several additional trips. I supervised and participated in the preparation of a report on the stratigraphic geology and a geologic map of the State, done in coöperation between the United States Geological Survey and the Florida State Survey, by Messrs. George Charlton Matson, Frederick G. Clapp, and Samuel Sanford. I have therefore had at my disposal not only the results of my personal work for the Geological Survey, but also those of Messrs. Matson, Clapp, and Sanford. The information derived from my association with the United States Geological Survey is here utilized with the permission of the Director of that Bureau, and my hearty thanks are extended to him for the privilege.

Through facilities afforded by Dr. Alfred G. Mayer, Director of the Department of Marine Biology of the Carnegie Institution of Washington, I have been able to visit all the principal keys belonging to the main line, to collect and study bottom samples between Miami and Key West, particularly the deposits accumulating behind the keys, to examine several important living coral reefs, and to make detailed investigations of the reefs around the Tortugas. I was also able to visit Cat and Gun keys and the Picquet rocks of the Bahamas.

It was at first contemplated to give an account only of the sedimentation now taking place in the bays and sounds behind the keys. Naturally, the questions arose, whence come these sediments, by what processes are they brought to the sea, how great is their quantity, and how are they distributed over the ocean floor? An extension of these questions led to a general consideration of sedimentation on the Floridian platform and the growth of the platform itself.

The scope of the paper was therefore enlarged, and an attempt is made to trace the geologic history of the Floridian Plateau from Oligocene to Recent time. The work of previous investigators has been extensively drawn upon, and the debt owed them is gratefully acknowledged. The principal of these are Louis Agassiz, Alexander Agassiz, Eugene A. Smith, Angelo Heilprin, William H. Dall, N. S. Shaler, Leon S. Griswold, George C. Matson, Frederick G. Clapp, Samuel Sanford, and E. H.

Sellards. Each of these men has made a distinct contribution to our knowledge of the geology and geologic history of the region.

In the preparation of this paper I have received assistance or advice from several of my scientific colleagues, and express my thanks for their kindness. Professor Charles E. Munroe advised me regarding some of the chemical problems; Mr. J. C. Hoyt supplied information on the surface run-off of streams on the Atlantic slope of the United States; Rear-Admiral Pillsbury, U. S. N., retired, discussed the oceanic currents with me; and Dr. Wm. H. Dall, Mr. George C. Matson, Mr. Samuel Sanford, Dr. L. W. Stephenson, and Dr. Paul Bartsch each read my manuscript. Mr. Matson made physical examinations of the bottom samples collected and has contributed the report published on pp. 120–125 of this paper, and Dr. Dall has furnished a note on the Suwanee Strait region during Miocene time.

Geologic research in Florida, and in Southern Florida particularly, is not now the difficult and hazardous task it was even 10 or 15 years ago. The Florida East Coast Railway has extended its line from the mainland along the keys, and canals have been cut into the Everglades, the excavations for both the railway and the canals revealing excellent exposures hitherto obscured by soil and dense vegetation. Numerous wells, of which we have records, have been put down on both the mainland and the keys, and the shallow-draft naphtha launch renders easy and speedy the examination of banks and keys hitherto accessible only with difficulty. The recently increased facilities for investigation have not been neglected, and results have been obtained sometimes at variance with former opinions, as might have been anticipated.

This is to be regarded as only a sketch of the geologic development of the Floridian Plateau, as many problems need solution and many phases of its history need further investigation. Perhaps its principal value may be in directing attention to some of the unsolved problems. It is necessary to know more accurately the amount of water discharged by the streams and the quantities of solids borne by them to the sea. The chemical processes of precipitation have not been sufficiently studied. Dall's researches on the paleontology of Florida have been epoch-making in their importance, but still our knowledge of the fossils of most of the geologic formations and horizons is far from complete. Additional paleontologic research is needed for every geologic formation known in the State, from the formations of the Vicksburg group to those of the Pleistocene. The paleontologic studies should be an accompaniment of more detailed stratigraphic work. Topographic maps and detailed geologic mapping are essential before the details of the successive deformations to which the area has been subjected can be ascertained. There is also great need for more extensive studies of the marine bottom deposits within the 100-fathom curve.

The deep wells recently put down on Key Vaca, Big Pine Key, and Key West have given valuable data, but deep wells are also needed on Key Biscayne or Virginia Key, the Marquesas, and the Tortugas, in order to discover what underlies the surface formations. It is important to ascertain whether the Miami oolite is older than or contemporaneous with the Key Largo limestone. A well on Old Rhodes or Elliott Key might give the desired information.

Probably a number of years will elapse before these deficiencies in the information on the geology of Florida will be supplied, as tedious and protracted research is necessary. It is hoped this paper may serve as a convenient summary of the present knowledge of the geologic history of this interesting region, perhaps present an interpretation somewhat different from those preceding, and be a stimulus to further investigation.

TOPOGRAPHY OF THE FLORIDIAN PLATEAU.

That the land surface of Florida represents only about half of the area of the Floridian Plateau has been known for a number of years. A. Agassiz has called attention to it in his "Three Cruises of the Blake"[1]; Shaler, in his "Topography of Florida"[2]; Dall, in his "Neocene" Correlation Paper[3]; and Sanford in his "Topography and Geology of Southern Florida."[4]

RELATION OF THE 100-FATHOM CURVE TO THE PRESENT LAND SURFACE AND TO GREATER DEPTHS.

The 100-fathom curve, which is considered the delimitation of the continental shelf, lies between 85 and 90 miles offshore, east of Fernandina; south of this locality it curves gently and gradually approaches the shore, until opposite Fort Lauderdale it is less than 5 miles distant. It follows closely the seaward face of the main line of the reefs, curves to the westward, passing between 10 and 15 miles south of Key West, about the same distance south of the Marquesas, and 20 miles south of the Tortugas, beyond which it bends to the north of west. The width of the Plateau along the 25° of latitude, which passes through Florida Bay, is between 240 and 250 miles. Just south of its intersection of the 25° parallel it takes a slightly curving course to the north of west and lies about 45 miles south of Pensacola. (See plate 1.)

The width of the Plateau along different parallels is given in the following table:

Width of the Floridian Plateau along Parallels of Latitude.

Parallel.	Total width.	West of land area.	Land area.	East of land area.
	miles.	*miles.*	*miles.*	*miles.*
Ten miles south of St. Augustine	405	205	135	65
29°	335	180	115	40
28°	310	130	140	40
27°	297	130	145	22
26°	266	160	100	7
25°	242	225	2[1]	15

[1] Distance across Key Largo.

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[1] Vol. 1, p. 152, 1888.
[2] Mus. Comp. Zool., Bull., vol. 16, p. 139, 1890.
[3] U. S. Geol. Surv., Bull. 84, p. 86, 1891.
[4] Florida Geol. Surv., 2d Ann. Report, p. 180, 1910.

The preceding measurements are made along parallels of latitude and are not precisely transverse to the long axis of the Peninsula, which is from N. 20° W. to S. 20° E., but they clearly indicate the approach southward of the 100-fathom curve to the shore, and the persistent width of the submarine portion of the Plateau on the west. In no instance is the width of the subaerial portion of the Plateau so great as that of the subaqueous portion. They are most nearly equal along parallel 27°.

In the Gulf of Mexico the descent from the 100-fathom curve is abrupt until a depth of 1,500 or 2,000 fathoms is reached. The steepest portion of this declivity is about 60 miles slightly north of west (N. 68° W.) of the Tortugas, where within 22 miles there is a drop from 100 to 1,500 fathoms, and within about 12 miles further an additional descent from 1,500 to 2,000 fathoms. The usual depth to the south in the Florida Straits is over 500 and less than 1,000 fathoms. Off Havana is a tongue of deep water, which the 1,000-fathom curve marks. The Florida Straits are from 500 to 1,500 fathoms shallower than the nearby bottom of the Gulf of Mexico.

The water between the southern portion of the east coast and the Bahamas is still shallower, being less than 300 fathoms in depth. The 500-fathom curve passes around the eastern side of the Bahamas. Off the eastern coast the descent from the 100-fathom curve is not nearly so precipitous or so great in amount as in the Gulf. In the Atlantic the 1,000-fathom curve is slightly sinuous, but follows a southerly course from near Hatteras to the eastern side of the Bahamas and forms the eastern boundary of the "Blake Plateau."[1]

THE 10-FATHOM CURVE.

The 10-fathom curve does not in all places lie close to the shore, indicating extensive areas of shoal water. It is about 25 miles offshore east of Fernandina and slightly less opposite Jacksonville, south of which it irregularly approaches the shore, coming very near it opposite Jupiter Inlet and from there to Key Biscayne. It closely follows the outer edge of the growing coral reefs, extends westward beyond the Marquesas and more than halfway from them to the Tortugas. It also incloses the Tortugas, but does not connect them with the Marquesas. North of the latter keys it bends eastward, lying between 40 and 45 miles west of the mouth of White Water Bay. Thence it runs northward to beyond the Thousand Islands, and from there roughly parallels the west coast. It is about 15 miles west of the mouth of Charlotte Harbor, about the same distance west of the mouth of Tampa Bay, 30 miles west of Cedar Keys, 10 miles south of Cape San Blas; westward of the last-mentioned locality it is from 5 to 10 miles offshore. (See plate 1.)

If Florida were elevated only 60 feet, all of the area surrounded by the 10-fathom curve would be added to the land surface. The whole of the key region, excepting the Rebecca Channel, would be above water-level, leaving the bottom of Florida Bay dry, as would also be a strip of land 25 miles wide opposite Fernandina, but narrowing southward on the east coast, and a strip from 10 to 30 miles wide on the west coast east

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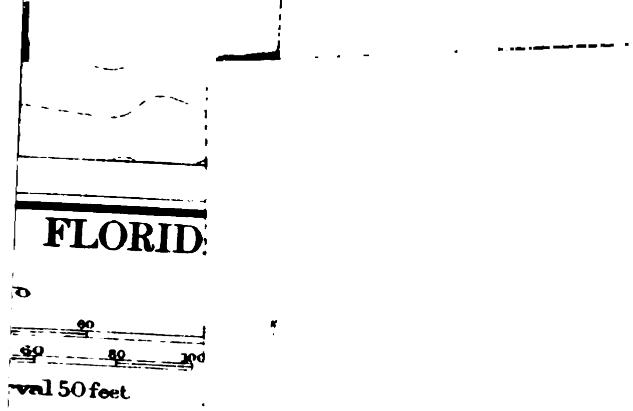
[1] A. Agassiz, Three Cruises of the Blake, p. 96.


FLORID
o
60
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100
val 50 feet

of the mouth of the Apalachicola River. Such a slight elevation would increase the land surface approximately one-third.

THE REEFS.

No attempt will be made to give a detailed account of the reefs, as the classic descriptions of Louis Agassiz[1] and Alexander Agassiz[2] are so well known. The reefs occur as a disconnected series just landward of the 10-fathom curve, between it and the main line of keys, extend from Fowey Rocks as far westward as the Marquesas, and disappear in the Tortugas. The northernmost living reef known is that at Fowey Rocks. L. Agassiz says[3] "in the immediate vicinity of Cape Biscayne there is a mud shoal, laid partly bare at low water, over which grow branching *Millepora*, with small tufts of *Oculina* and *Caryophyllia*[4] rising between them, and here and there a few *Porites furcata*."

On the surface of the tongue of land east of the northern end of Biscayne Bay and Virginia Key, I collected wave-tossed, dead specimens of the following corals: *Cyphastrea hyades*, *Orbicella annularis*, *Orbicella cavernosa*, *Mussa* (*Isophyllia*) sp., *Favia fragum*, *Mæandra areolata*. The original source of these specimens was not determined.

I found living specimens of *Siderastrea radians* and *Porites* forma *furcata* off the northeastern end of Key Biscayne in water from 2.5 to 4 feet deep. The living corals do not form a reef, but grow on a sandy flat.

Professor Shaler's report[5] of the extension of the Florida reef as far north as Hillsboro River is not convincing. An occasional coral does not mean a coral reef; besides "*Manicina*" *areolata* is, according to my experience with Florida corals, not a reef coral, strictly speaking. Its habitat is on protected flats. The species cited, when found alone, rather indicates the absence of a reef.

The water over the reefs is always shoal. The following table, compiled from United States Coast Survey charts, gives the names of the principal reefs from Fowey Rocks southward, and the depths of water over them. It shows that the reefs occur between water-level at low tide and depths of 18 to 20 feet. The reefs, as already stated, are disconnected, with passages a few fathoms—usually 9 to 12 feet, always less than 10 fathoms—between them.

Name.	Depth in feet.	Name.	Depth in feet.
Fowey Rocks	1 to 9	Tennessee Reef	2 18
Triumph Reef	3 15	Coffin's Patches	5
Ajax Reef	5 12	East Washerwoman	3 12
Pacific Reef	3 11	Sombrero Key	4 5
Carysfort Reef	3 19	American Shoal	3 16
French Reef	1	Pelican Shoal	3 4
Molasses Reef	1 4	Sambo	1
Pickles Reef	1 4	Sand Key	6 8
Conch and Little Conch reefs	2 8	Marquesas	3 8
Crocker Reef	2 5	Tortugas Water-level	15 20
Alligator Reef	4 5		

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[1] Report on the Florida Reefs, Mus. Comp. Zool., Memoirs, vol. VII, 1880.

[2] Three Cruises of the Blake, vol. I, Chapter III, 1888.

[3] *Op. cit.*, p. 16.

[4] Probably *Cladocora*.

[5] Mus. Comp. Zool., Bull., vol. 16, p. 148.

THE HAWK CHANNEL.

Behind the keys is an open-water channel, known as Hawk Channel, having shoals from place to place in it and extending from the upper end of the series of reefs to the Marquesas. Its maximum depth is from 5.5 to 6 fathoms, and its width varies from 3 to 7 miles. The landward boundary is formed by the main line of keys.

THE KEYS.

The Florida Keys are a series of islands rising slightly, a maximum of 10 to 12 feet above tide-level, forming a curve paralleling the reefs, bounded by the landward side of the Hawk Channel as far as the Marquesas, and extending from the seaward face of Biscayne Bay to the Tortugas. In form these keys may be divided into three groups:

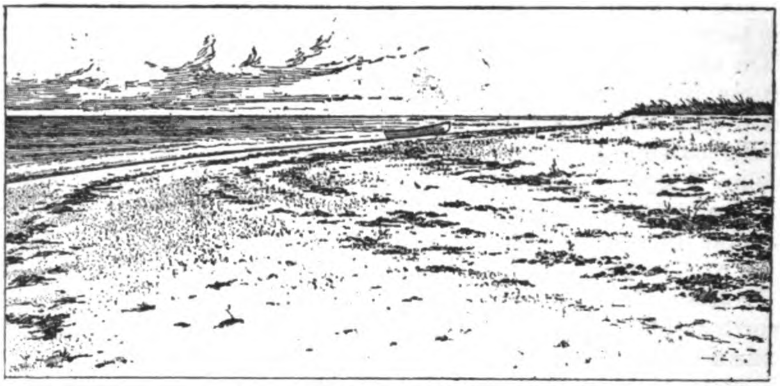

Fig. 1.—Tortugas, East Key, west side looking north. Note vegetation on the summit of the key.

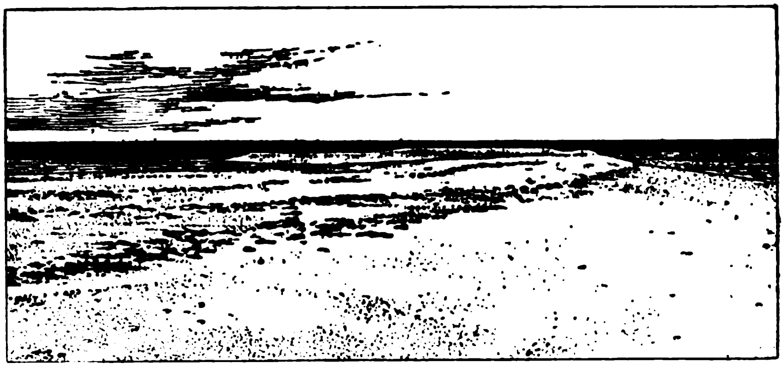

Fig. 2.—Middle Key looking north along the axis. This key was washed away during a storm on June 28, 1909, but was restored between August, 1909, and May, 1910.

(1) The first group consists of long, narrow islands, stretching along a gentle curve to the southwest from Biscayne Bay to Bahia

Honda Key. Key Largo, the largest, has a maximum width of about 3.5 miles and is about 27 miles in length.

(2) Beginning with Little Pine and No Name keys, the axis of elongation is from northwest to southeast, or practically at right angles to the first group. This group includes the keys between Bahia Honda and Boca Grande, although one key, Key West, has its longer axis east and west, and not north and south. The largest of these keys, Big Pine, has the following dimensions: length 8 miles, width of southern end 2.375 miles, average width about 1.25 miles.

(3) The third group comprises the rather typical atoll of the Marquesas and the less perfect one of the Tortugas.

In composition the keys represent four types:

(1) The most northern group, comprising Virginia Key and Key Biscayne, has its surface composed of sands, largely arenaceous (plate 6, figs. *a* and *b*).

(2) Those from Soldier Key to Bahia Honda inclusive and the southern end of Big Pine are elevated coral reef rocks (plate 15, figs. *b* and *c*).

(3) The group from Little Pine and No Name to Boca Grande are formed of oolite, the Key West oolite (plate 14, fig. *c;* 15, fig. *a*).

(4) The Marquesas and the Tortugas show on their surfaces the more or less comminuted remains of the calcareous skeletons of organisms, mollusks, corals, nullipores, etc. (plate 6, fig. *c;* 7, figs. *a* and *b*, and text figs. 1 and 2).

THE BAYS AND SOUNDS BEHIND THE KEYS.

The landward face of the keys is bounded by a series of bays and sounds, beginning at the north with Key Biscayne, followed, going southward, by Card, Barnes, Blackwater, and Hoodoo sounds, and terminated westward by the Bay of Florida.

Biscayne Bay has a more pointed northern end, bounded on the eastward by a sandy spit of land, Virginia Key, and Key Biscayne, between which are passages. Its southern portion is wider, bounded on the east by Sands, Elliott, and Old Rhodes keys, and has an obtuse termination before communicating with Card Sound, to the south. The length of this bay is 35 miles, maximum width 10 miles, maximum depth 17 feet. Featherbed Bank extends across its median portion and makes two divisions.

Card Sound has its northern end almost opposite the northern end of Key Largo, toward which point is a projection from the mainland; its southern end is formed by a spur projecting from Key Largo toward the mainland. The length of this sound is 6 miles, width 3 to 3.5 miles, maximum depth 12.5 feet.

Barnes Sound has as its northern boundary the spur from Key Largo, forming the lower end of Card Sound; its southern boundary is formed by projections from Key Largo and the mainland. Its length is 6.5 miles, width 5.5 miles, maximum depth 11 feet.

Blackwater Sound is south of Barnes Sound, and has its northern boundary determined by the features forming the southern boundary of the latter. Its lower boundary is formed by spurs from the mainland and Key Largo. This sound is quadrangular in outline; length 4 miles, width 3.5 miles, maximum depth 9 feet.

Hoodoo Sound is a small body of water lying within the western part of the spur of Key Largo, which forms the southern boundary of Blackwater Sound. It has a length of 1.5 miles, width 0.5 mile, depth 8.5 feet.

Florida Bay is of cornucopia shape, with its narrower end at the western outlets of Blackwater and Hoodoo sounds. The width of the upper end is about 10 miles; it opens toward the west and is 27 miles wide south of Cape Sable. The water also deepens toward the west from 4 to 7 feet, at its upper end, to 10 to 12 feet between Cape Sable and Key Vaca; farther westward it deepens to 12 to 14 feet, and then gradually slopes to the 10-fathom line in the Gulf.

Keys, Mud Flats, and Shoals in the Bays and Sounds.—Here it need only be mentioned that behind the main keys and betweeen them and the mainland are keys mostly overgrown with mangroves, mud flats exposed at low tide, and shoals built almost to water-level. The axes of these keys and banks trend from north to south, at right angles to the main keys, which are elongated from northeast to southwest. Their origin will be especially discussed in succeeding pages.

To summarize the features occurring between the 10-fathom curve and the shore of the mainland, there are:

(1) The reefs lying just inside the 10-fathom curve.
(2) The Hawk Channel, separating the reefs from the main line of keys, varying in width from 3 to 7 miles and having a maximum depth of 5 or 6 fathoms.
(3) The main keys.
(4) The bays and sounds separating the keys from the mainland.

RÉLIEF OF THE MAINLAND.

In the following remarks the physiography of the mainland will not be treated in detail, the purpose being to consider the land surface as only a subaerial portion of the more extensive Floridian Plateau. Matson and Clapp have compiled a topographic map of the State, with 50-foot contour intervals. This map, although it does not claim to be without minor inaccuracies, gives the best available information on the relief of the land surfaces. (Plate 1, the subaerial topography.)

Florida is a land of low relief, perhaps two-thirds of it lying below the 50-foot contour. This line extends far up St. Mary's River on the northern boundary of the State, whence, proceeding southward, it passes about 9 miles west of Jacksonville and through Palatka on the west side of St. John's River. On the east side of the latter river, from just below Palatka to the latitude of Lake Monroe, it circumscribes a ridge. It continues down the west side of St. John's River, extending up its tributaries and passes well to the north of Lake Okeechobee, at least 15 or 20 miles. On the western side of the Peninsula it lies above the level of Arcadia on Peace River; it passes around the head of Tampa Bay, thence northward to Dunnellon at a distance of from 5 to 12 miles from the coast; thence it bends to the northwest and west, keeping from 10 to 25 miles from the shore in the interstream areas, while it digitates up the various rivers and other streams.

If Florida were depressed 50 feet the greater portion of the Peninsula would be submerged—or most of Florida is less than 10 fathoms above sea-level.

The 100-foot contour is not a continuous line around the whole Peninsula, but circumscribes disconnected areas. One of these areas lies west of Kissimmee River, extends from Summit in Marion County southward to near Zolfo Springs in De Soto County, and has its western boundary determined by Hillsboro and Withlacoochee rivers.

There is another ridge, rising above 100 feet, between Dunnellon and Dade City on the west coast. Between Dunnellon and Hawthorne are other but isolated areas above the 100-foot level. From Gainesville northward, lying between the valleys of St. John's and Suwanee rivers, is another area above this level. West of the Suwanee River the 100-foot contour is present on all interstream lobes.

If Florida were depressed 100 feet there would remain of the present land surface of the Peninsula four large and a number of smaller islands.

The 150-foot level is attained in each of the four areas surrounded by the 100-foot contour. Haines City is situated on a ridge extending southward from near the northern boundary to near the southern boundary of Polk County. West of Dade City is another ridge over 150 feet in elevation. Between Dunnellon and Hawthorne are isolated peaks above this level. Between St. John's and Suwanee rivers on the north considerable areas are circumscribed by this contour.

The areas circumscribed by the 200-foot contour are much smaller. Haines City, De Soto County, is located on one of them, and south of that town the map indicates five others on the north and south ridge through Polk County. Four hills over 200 feet in altitude are in northern Pasco County, west of the longitude of Dade City. The only other 200-foot elevation on the Peninsula is the Trail Ridge, along the north and south boundaries of Baker-Duval and Bradford-Clay counties.

The only 250-foot elevation indicated on the Peninsula by the map is south of Haines City in central Polk County.

If the Floridian Plateau were depressed 250 feet (about 42 fathoms) only one small island, about 5 miles long and 2.5 miles wide, situated in central Polk County, would remain of the present land surface of the Peninsula. If the 100-fathom curve is taken as the submarine limit of the Floridian Plateau, it immediately becomes evident that in vertical measure the submarine exceeds the subaerial portion by 58 fathoms: or $\frac{100}{142}$ is below water, while $\frac{42}{142}$ is above water.

In the preceding account, the remarks have been confined to the relief of the Peninsula of Florida, as the westward extension belongs more properly to the continental mass forming the northern boundary of the Gulf of Mexico. In this portion of the State there are higher elevations than on the Peninsula; at Mount Pleasant is a small area over 300 feet in elevation, and considerable areas are above 250 feet. Mossyhead is 264 feet above tide, and near the Alabama line some localities may be somewhat higher, small areas perhaps exceeding 300 feet.[1]

Before leaving the subject of the relief of the subaerial portion of the Plateau, two features should be mentioned. All areas delimited by contours above the 50-foot lie to the west of St. John's and Kissimmee rivers and north of the latitude of Sarasota. Most of the lakes of the State occur in the more elevated region, or along its western or southern periphery. This distribution of more elevated areas, particularly with reference to drainage lines, will be discussed subsequently.

MARINE BOTTOM DEPOSITS FORMING IN THE BAYS AND SOUNDS BEHIND THE KEYS.

During the latter part of April, 1908, I went from Miami to Key West on the yacht *Physalia*; and also made a short excursion from Miami to Cat and Gun keys of the Bahamas. The route followed from Miami to Bahia Honda Key was that known as the "inside passage," but several short side-excursions were made outside the main line of the keys in a smaller launch. One object of making the trip within the main line of the keys was to procure bottom samples, particularly for ascertaining the nature of the deposits now being laid down behind the keys.

The specimens were procured by attaching a cup to the bottom of the sounding lead; they were then put into glass bottles with screw tops and brought to the laboratory for more detailed investigation. The material after arriving in the Geological Survey office was placed in the hands of Mr. G. C. Matson for examination. His report is given on subsequent pages.

For convenience of discussion the material will be described from (1) Biscayne Bay, (2) Card Sound, (3) Barnes Sound, (4) Blackwater Sound, (5) Hoodoo Sound, (6) Florida Bay, (7) Material from Cat and Gun keys, Bahamas.

A few beach specimens will be discussed in connection with the bottom deposits of the neighboring waters, and in a similar connection a few bottom specimens obtained from the outside of the keys will be considered.

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[1] G. C. Matson, Preliminary Report on the Geology of Florida, Fla. Geol. Surv., 2d Ann. Report, p. 30.

List of Localities from which Bottom Samples were Obtained.

(See plate 2, localities platted on the map.)

Specimen No.	Locality.	Depth. *Feet.*
1	Junction of the two canals off mouth of Miami River	....
2	Oolite from dredged canal to main ship channel in Biscayne Bay	....
3	Midway between main ship channel and West Point, Key Biscayne, between buoys 7 and 4	12
4	Northern end of Key Biscayne, Bear Cut, Biscayne Bay	....
5	Opposite West Point, Key Biscayne, Biscayne Bay	13
6	Off eastern shore of Cat Key, south of passage between it and Gun Key (Bahamas).	9
7	Off eastern shore of Gun Key, north of passage between it and Cat Key (Bahamas).	About 12
8	Calcareous sand from shore, above tide, eastern face of Gun Key (Bahamas)	....
9	Calcareous beach sand, western face of Cat Key (Bahamas)	....
10	Mainland north side of New Cut, Biscayne Bay	....
11	North side of Norris Cut between Biscayne Bay and ocean	....
12	Northeastern corner of Key Biscayne	2.5
13	South of eastern end of Featherbed Bank	About 8
14	Lower Biscayne Bay, deepest portion, southwest of Sands Cut	12
15	West of Rubicon Key, off mouth of Cæsar Creek, lower end of Biscayne Bay	11
16	0.5 mile west of inner end of Cæsar Creek, lower end of Biscayne Bay	9
17	Off eastern end, western side of Elliott Key, 50 feet offshore	2 to 4
18	Hawk Channel, off mouth of Broad Creek, 2 miles offshore	18
19	0.5 mile east of mouth of Angelfish Creek	12
20	Northern end of Card Sound, inner end of Broad Creek	About 9
21	Card Sound, west of Pumpkin Key, about 200 feet offshore	12
22	Card Sound, southwestern end, 0.5 mile west of Key Largo, and 0.5 mile north of spur at lower end of the Sound	About 10
23	Steamboat Creek, between Card and Barnes sounds	12
24	Barnes Sound, near mouth of Steamboat Creek	About 12
25	Barnes Sound, center of the Sound	11
26	Blackwater Sound, upper end, off mouth of Jewfish Creek	12
27	Blackwater Sound, 0.5 mile northeast of Bush Point	9
28	Lower end of Hoodoo Sound	About 6
29	Bay of Florida, entrance from Hoodoo Sound	9
30	Bay of Florida, shoal, 2 miles northeast of Pigeon Key	1
31	The material composing Pigeon Key	....
32	Off inner end of Tavernier Creek	7
33	Shoal southwest of Tavernier Creek about a mile off Long Island	1
34	On Line between McGinty and Torrey keys	6
35	1 mile northwest of Shell Key	9
36	Southwestern end of cut across the bank south of Bowlegs Key	7
37	2.25 miles northwest of upper end of Long Key	6
38	1 mile west of north of western end of Long Key	6
39	1.25 miles north and east of end of Grassy Key	12
40	1 mile N. N. E. of Bamboo Key	9
41	0.75 mile north of eastern end of Stirrup Keys	9
42	1 mile northeast of the western end of Key Vaca	6
43	0.5 mile S. E. of Porpoise Key	4
44	0.25 mile W. N. W. of northern end of No Name Key	9
45	Middle of channel between No Name and Big Pine keys opposite middle of No Name Key	9
46	Eastern shore of No Name Key, opposite middle of island, 100 to 200 feet offshore	2.5
47	0.75 mile north of Bahia Honda Key	12

BISCAYNE BAY.

From the vicinity and bottom of this bay thirteen samples, including a few beach specimens and one off the northeast corner of Key Biscayne, were obtained. These specimens are Nos. 1 to 5 and 10 to 17 of the list.

Specimen No. 2 and some dredged material obtained in digging the canal from Miami to New Cut, which crosses the southern end of the cape east of Miami, show that the Miami oolite extends beneath the northern end of Biscayne Bay and at least partially forms its floor.

Specimens collected on the north side of New Cut (No. 10) and on the north side of Norris Cut (No. 11) are composed of calcareous and siliceous constituents. There is at both localities a considerable amount of fine quartz sand.

Specimen No. 4, which comes from the northern end of Key Biscayne, Bear Cut, contains an abundance of quartz mixed with shell fragments and amorphous carbonate of lime. The special point in calling attention to the specimens from the southern end of the cape on the east side of Biscayne Bay and from the two succeeding keys to the south, Virginia Key and Key Biscayne, is to emphasize the presence on them of a large proportion of quartz sand. Cape Florida, which is the southern extremity of Key Biscayne, has its surface covered by siliceous sand with an admixture of comminuted shells.

Soldier Key, the next key to the south of Cape Florida, has on its summit and western side a coating of siliceous sand underlain by elevated coral reef rock. Proceeding southward along the main line of keys the siliceous constituents progressively diminish.

Attempts were made to obtain bottom samples at two places on the east side of Key Biscayne, but in both instances the bottom was hard and no specimens were procured.

Three bottom samples were obtained from the northern end of Biscayne Bay, Nos. 1, 3, and 5. Specimen No. 1, which was collected a short distance off the mouth of the Miami River, showed shell fragments, amorphous carbonate of lime, much quartz sand, sponge spicules, and diatoms. The presence of quartz sand is to be expected, as it forms the surface coating over the Miami oolite of the surrounding country. Specimen No. 3, which was taken between the mouth of the Miami River and the western point of Key Biscayne in about 12 feet of water, was composed mostly of shell fragments and amorphous carbonate of lime, with very little quartz. Specimen No. 5, which was taken in about 13 feet of water off West Point, Key Biscayne, was also composed of shell fragments, amorphous carbonate of lime, and considerable quartz, with some sponge spicules and diatoms.

One specimen, No. 12, collected from the northeast corner of Key Biscayne, depth 2.5 feet, contained shell fragments, calcite, amorphous carbonate of lime, and considerable fine quartz, the quartz passing through the 40 and 80 to the inch mesh sieves, showing some silica on the sea floor east of this key. The bottom off the southwest corner of Key Biscayne consists of calcareous ooze and comminuted shells.

Five specimens, Nos. 13 to 17, were obtained from the southern end of Biscayne Bay, from the latitude of Sands Key southward. An inspection of Mr. Matson's table will show that most of the material is fine; by far the larger portion passed through the 40-mesh sieve but was retained by the 80. Quartz is abundant in No. 13, and there is some in Nos. 14, 15, and 16. In No. 16, however, the siliceous component is comparatively small in amount, while in No. 17 fine quartz, all of which passes through No. 80 sieve, is rare.

These observations on the bottom deposits of Biscayne Bay indicate that considerable quartz is being washed into the northern end of the bay, and that as one proceeds southward the calcareous constituents become predominant, while the siliceous constituents become insignificant. The material, when collected, consisted mostly of oozes and no intimation of the formation of oolite was observed.

BETWEEN OLD RHODES BANK AND CARYSFORT REEF LIGHT.

Two specimens, Nos. 18 and 19, were collected between Old Rhodes Bank and Carysfort Reef Light. Both of these specimens consisted mostly of shell fragments, amorphous carbonate of lime, sponge spicules, diatoms, and a very little quartz. In this region quartz is rare outside the main line of keys.

CARD SOUND.

Three specimens were collected from this sound, Nos. 20, 21, and 22, and one, No. 23, was taken from Steamboat Creek between Card and Barnes sounds. Nos. 20 and 21 both contained considerable quantities of quartz as well as shells, shell fragments, amorphous carbonate of lime, sponge spicules, and diatoms. In No. 22, however, quartz was rare. Specimen No. 23 from Steamboat Creek consisted mostly of organic matter with some amorphous carbonate of lime, sponge spicules, diatoms, and a very little quartz.

BARNES SOUND.

Only two specimens were taken from Barnes Sound, the first, No. 24, near the mouth of Steamboat Creek, at a depth of about 12 feet; the other, No. 25, near the center of the sound, depth about 11 feet. Specimen No. 24 in Mr. Matson's table is queried and perhaps should be omitted from the discussion. No. 25 consists mostly of shells, shell fragments, amorphous carbonate of lime, sponge spicules, and diatoms, with very little quartz, indicating a progressive diminution of quartz toward the southwest.

BLACKWATER SOUND.

Two samples, Nos. 26 and 27, were obtained from this sound. No. 27, it appears, was lost. No. 26, which was taken from the upper end of the sound off the mouth of Jewfish Creek, depth 12 feet, consisted of organic matter, shells, shell fragments, calcite and aragonite, sponge spicules, and a little quartz was retained by sieves Nos. 40 and 80. Material thrown out of a canal dredged between Blackwater and Hoodoo sounds was similar to that forming the bottom of the neighboring sounds, except molluscan remains are so abundant as to constitute a shell marl.

HOODOO SOUND.

This is a small sound between the lower end of Blackwater Sound and Florida Bay. One specimen, No. 28, was obtained from it at a depth of about 6 feet. The material was similar to that from Blackwater Sound with somewhat less quartz.

FLORIDA BAY.

Specimens Nos. 29 to 47 were taken from Florida Bay. Nos. 39 to 42, and No. 47, were procured on the north side of the keys elongated in a northeast-southwest direction. Nos. 43 to 46 were collected along the group of keys lying slightly to the west of Bahia Honda and elongated in a northwest-southeast direction.

North Side of Key Largo.—Nos. 29, 30, and 32 were obtained north of Key Largo in depths ranging from 1 foot to 7 feet; No. 31 is from the surface of Pigeon Key. The material in general was similar in composition, except the quantity of shells and shell fragments varied. Only one sample, No. 31, which is the surface material of Pigeon Key,[1] contained any quartz. No. 32 was taken off the inner end of Tavernier Creek, which forms the lower limit of Key Largo.

North of Long Island.—One sample, No. 33, was collected on the shoals northwest of Tavernier Creek, about a mile off Long Island. The material consisted of shells, amorphous carbonate of lime, sponge spicules, and diatoms; no quartz was noticed.

North of Upper Matecumbe.—Between McGinty and Torrey keys one specimen, No. 34, was obtained. It consisted of shell fragments, amorphous carbonate of lime, sponge spicules, diatoms, and some calcite, and in the material retained by sieves Nos. 80 and 100 considerable quartz was observed in the 22.9 per cent of the total weight of the sample examined. This sample shows that quartz has worked its way as far to the southwest as a point nearly opposite the lower end of Upper Matecumbe Key. The bottom of the channel southwest of Shell Key is swept clean by the currents passing between Upper and Lower Matecumbe keys.

North of Lower Matecumbe.—Two samples, Nos. 35 and 36, were obtained on the north side of this key: No. 35, a mile northwest of Shell Key; No. 36, the southwestern end of the cut across the banks south of Bowlegs Key. Both specimens consisted mostly of shell fragments, amorphous carbonate of lime, sponge spicules, and diatoms, with very little quartz.

North of Long Key.—A specimen, No. 37, obtained from 2.25 miles northwest of the upper end of Long Key, consisted mostly of calcareous material with sponge spicules and diatoms. There was very little quartz and a few calcareous oval grains. There is some doubt about the identification of the specimens from localities 38 and 39 and they are omitted from the discussion. However, the bottom a mile west of north of the western end of Long Key is hard, being swept almost clean by currents passing between Long and Grassy keys. The bottom material north of Grassy Key is a calcareous ooze with a little quartz (field examination).

North of Key Vaca.—Specimens Nos. 40, 41, and 42 were collected along the north side of this key. The material consisted of shell fragments, amorphous carbonate of lime, sponge spicules, and diatoms. There were a few oval grains in specimen No. 40 and a very little quartz in each of the three. The bottom between Key Vaca and Bahia Honda, midway between Molasses and Duck keys, depth 9 feet, is hard and covered by a thin coating of shells and shell fragments.

North of Bahia Honda.—Specimen No. 47 was obtained 0.75 mile north of this key in a depth of 12 feet It consisted of shell fragments, amorphous carbonate of lime, sponge spicules, diatoms, and a very little quartz. Bahia Honda is the westernmost of the main line of keys with a northeast-southwest trend.

No Name and Big Pine Keys.—Four specimens, Nos. 43, 44, 45, and 46, obtained in this vicinity, consist mostly of calcareous material with some sponge spicules and diatoms. Oval grains were in three specimens,

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[1] This is important in indicating the southward extent of surficial quartz.

Nos. 43, 45, and 46, and these specimens also contained a small proportion of quartz.

The bottom samples show that quartz is disseminated over the entire area of the bottom of Florida Bay; however, in comparison with the calcareous constituents the proportion of quartz in the southwestern corner of the bay is extremely small.

GUN AND CAT KEYS, BAHAMAS.

Four specimens, Nos. 6 to 9, were obtained from the sea-bottom and the beaches of these two keys for purposes of comparison with the material from the Florida keys. Specimens Nos. 6 and 7 were, respectively, from the eastern shore of Cat Key, south of the passage between it and Gun Key, and off the eastern shore of Gun Key, north of the passage between it and Cat Key. The material consisted of shell fragments, amorphous carbonate of lime, sponge spicules, and diatoms, also a little aragonite and calcite. Specimen No. 6 contained a little quartz which did not pass through mesh No. 80. This material is very similar to that from the region of Key Vaca and Bahia Honda, with perhaps a smaller quantity of quartz. Specimen No. 8 was from the eastern shore of Gun Key, above tide, and No. 9 is beach sand from the western face of Cat Key. This material was similar in composition to that taken from the bottom except no quartz whatever was observed. It should be noted that specimens Nos. 6, 8, and 9 all contained oval grains of amorphous carbonate of lime. The nature of these grains will be alluded to in the comparison of the lithologic specimens from the Bahamas with those from the vicinity of the Miami and Key West oolites.

SUMMARY OF DATA ON THE MATERIAL OF THE DEPOSITS.

The material at present being laid down inside of the keys consists mostly of silica and carbonate of lime. Silica is abundant in the form of sand in the northern portion of Biscayne Bay, it becomes rarer toward the southwest, and is present in small quantities as far as Big Pine Key. Toward the southwest, as the siliceous material becomes rarer, calcium carbonate becomes progressively more abundant, occurring as a flocculent sediment or ooze over practically the entire region from the lower portion of Biscayne Bay to the gulf end of Florida Bay.

REPORT ON EXAMINATION OF MATERIAL FROM THE SEA-BOTTOM BETWEEN MIAMI AND KEY WEST.

By George Charlton Matson.

"The accompanying table gives the results of physical and microscopic examination of the sea-bottom materials obtained among the Florida keys. The physical examination was made by passing the material through standard sieves having respectively 20, 40, 80, 100, and 200 meshes to the inch. The percentage of each sample remaining upon the different sieves and the percentage which passed through the 200-mesh sieve were determined by weight. Before sifting, the material was carefully ground in a mortar to separate the grains which were aggregated, care being exercised to avoid crushing the individual grains. In this work considerable difficulty was experienced with the finer-grained specimens because the grains adhered to each other with such tenacity that it was hard to separate without pulverizing them.

"After grinding, a sample was taken for sifting. In order to have the results of the examination of the different specimens comparable, samples of as nearly uniform size as possible were used; the weight of the samples being fixed at 13 grams. In dealing with samples so small, it was necessary to use an accurate balance, because an error of one-tenth of a gram would amount to nearly 1 per cent. For this reason a chemical balance was used, and the weights were determined to thousandths of a gram. The percentage of the material of different sizes was computed from the weights.

"The microscopic study included an examination of each sample after sifting. This examination was made by mounting the material in water and studying it with a petrographic microscope. It was found that the coarse material consisted largely of shells and shell fragments and that amorphous lime carbonate formed a large percentage of most of the samples which passed through the 40-mesh sieve. A few specimens were composed of almost pure quartz sand and this material was found in smaller quantities in specimens from nearly all of the localities.

"Calcite and aragonite in the form of small fragments were present in many specimens and in two cases spherules of chalcedony were observed. Some of the specimens contained oval grains of carbonate of lime which may possibly have an oolitic structure, though such slides as we now have show nothing but aggregated calcite in a finely divided state.

"Sponge spicules and diatoms were noted in many cases and they are probably to be found in all cases where there is amorphous carbonate of lime, but they were seldom detected without first dissolving the lime in acid. After treatment with acid there was a gelatinous residue which blackened on exposure to the air. It is doubtless organic matter of some sort." (For a list of the localities by numbers see p. 115; see map, plate 2, on which the localities are platted.)

Table giving results of physical and microscopic examination of sea-bottom materials obtained among Florida Keys.

Specimen No.	Weight of sample (grams).	Per cent and description of material retained on 20-mesh sieve.	Per cent and description of material retained on 40-mesh sieve.	Per cent and description of material retained on 80-mesh sieve.	Per cent and description of material retained on 100-mesh sieve.	Per cent and description of material retained on 200-mesh sieve.	Per cent and description of material passing 200-mesh sieve.
1	8.208	12 p. ct. Shells, amorphous carbonate of lime.	11.6 p. ct. Amorphous carbonate of lime sand and shell fragments. Quartz sand common.	47.3 p. ct. Amorphous carbonate of lime sand 0.75, quartz sand 0.25.	19.2 p. ct. Chiefly quartz sand, some amorphous carbonate of lime sand.	8.8 p. ct. Chiefly quartz sand, some amorphous carbonate of lime sand, sponge spicules and diatoms.	1.1 p. ct. About 0.3 quartz, remainder amorphous carbonate of lime, sponge spicules and diatoms.
2	Some large fragments of limestone.						
3	13.000	1.8 p. ct. Shells and shell fragments.	11.6 p. ct. Shell fragments and amorphous carbonate of lime sand. Quartz rare.	13.6 p. ct. Amorphous carbonate of lime sand. Quartz rare.	10.5 p. ct. Amorphous carbonate of lime sand. Quartz rare. Sponge spicules and diatoms.	27.2 p. ct. Like 100.	35.3 p. ct. Like 100.
4	12.558	5.9 p. ct. Shell fragments.	12.6 p. ct. Shell fragments, quartz abundant.	56.1 p. ct. Amorphous carbonate of lime sand. Quartz 0.2 of whole.	See 80. Amorphous carbonate of lime and quartz about equal proportions.	11.9 p. ct. Chiefly quartz some amorphous carbonate of lime.	13.5 p. ct. Chiefly quartz some amorphous carbonate of lime, sponge spicules and diatoms.
5	12.820	1.6 p. ct. Shells and shell fragments.	12.8 p. ct. Amorphous carbonate of lime sand. Quartz common.	29.0 p. ct. Same as 40.	20.3 p. ct. Amorphous carbonate of lime sand. Quartz 0.2 of whole.	24.3 p. ct. Amorphous carbonate of lime sand. Quartz 0.16 of whole. Sponge spicules and diatoms.	22.0 p. ct. Amorphous carbonate of lime, quartz rare, sponge spicules and diatoms.
6	13.000	6.7 p. ct. Shells and shell fragments.	12.2 p. ct. Like 20.	35.9 p. ct. Amorphous carbonate of lime — smooth oval grains. Quartz rare.	9.9 p. ct. Amorphous carbonate of lime. Some crystalline, diatoms and sponge spicules.	19.4 p. ct. Amorphous carbonate of lime, aragonite, diatoms and sponge spicules.	15.9 p. ct. Amorphous carbonate of lime, sponge spicules and diatoms.
7	6.076	3.0 p. ct. Shell fragments and amorphous carbonate of lime.	12.9 p. ct. Like 20 with some oval grains.	21.6 p. ct. Amorphous carbonate of lime sand, sponge spicules and diatoms.	11.7 p. ct. Like 80.	30 p. ct. Like 80.	20.8 p. ct. Like 80. Some aragonite and calcite.
8	13.000	0.4 p. ct. Shell fragments and amorphous carbonate of lime.	7.3 p. ct. Amorphous carbonate of lime, some oval grains.	44.2 p. ct. Some shells, mostly oval grains. Amorphous carbonate of lime.	24.2 p. ct. Like 80, with much calcite, diatoms and sponge spicules.	10.7 p. ct. Like 100.	13.2 p. ct. Like 100 with much calcite.
9	13.000	0.5 p. ct. Shell fragments.	36.1 p. ct. Amorphous carbonate of lime, mostly oval.	62.7 p. ct. Like 40.	0.6 p. ct. Like 40.	0.1 p. ct. Like 40.	

Table giving results of physical and microscopic examination of sea-bottom materials obtained among Florida Keys.—Continued.

Specimen No.	Weight of sample (grams).	Per cent and description of material retained on 20-mesh sieve.	Per cent and description of material retained on 40-mesh sieve.	Per cent and description of material retained on 80-mesh sieve.	Per cent and description of material retained on 100-mesh sieve.	Per cent and description of material retained on 200-mesh sieve.	Per cent and description of material passing 200-mesh sieve.
[1]10	13.000	2.3 p. ct. Shell fragments and amorphous carbonate of lime. Quartz rare.	22.9 p. ct. Amorphous carbonate of lime and quartz 0.2 of whole.	61.5 p. ct. Amorphous carbonate of lime sand, quartz 0.5 + of whole.	5.9 p. ct. Quartz and amorphous carbonate of lime, about equal.	3.2 p. ct. Amorphous carbonate of lime sand. Quartz common.	4.2 p. ct. Like 200, sponge spicules and diatoms.
11	13.000	1.2 p. ct. Shells, amorphous carbonate of lime and quartz.	15 p. ct. Amorphous carbonate of lime sand. Quartz about 0.1.	76.7 p. ct. Amorphous carbonate of lime and quartz, about equal.	5.5 p. ct. Amorphous carbonate of lime sand. Quartz about 0.25.	0.2 p. ct. Like 100.	
12	13.000	4.6 p. ct. Shell fragments.	11 p. ct. Shell fragments, calcite.	45.7 p. ct. Amorphous carbonate of lime. Quartz about 0.2.	32.5 p. ct. Quartz 0.75, amorphous carbonate of lime 0.25.	6.4 p. ct. Quartz, amorphous carbonate of lime rare.	
[2]13	13.000	0.3 p. ct.	13.9 p. ct.	26.9 p. ct.	18.1 p. ct.	15.9 p. ct.	24.9 p. ct.
14	13.000	0.9 p. ct. Chiefly quartz, some organic matter containing diatoms, &c.	20.9 p. ct. Like 20.	54 p. ct. Like 20. More amorphous carbonate of lime.	9.5 p. ct. Amorphous carbonate of lime. Quartz.	8.3 p. ct. Amorphous carbonate of lime, organic matter, sponge spicules and diatoms. Quartz 0.25.	7.7 p. ct. Amorphous carbonate of lime, organic matter, sponge spicules and diatoms.
15[1]	13.000	2.4 p. ct. Shell fragments 0.5, quartz 0.5.	24.9 p. ct. Amorphous carbonate of lime 0.1, quartz 0.9.	48.1 p. ct. Chiefly quartz a little amorphous carbonate of lime.	12.5 p. ct. Amorphous carbonate of lime 0.5, quartz 0.5.	7 p. ct. Amorphous carbonate of lime 0.8, quartz 0.2, sponge spicules and diatoms.	5.1 p. ct. Amorphous carbonate of lime, quartz rare, sponge spicules and diatoms.
16	13.000	10.1 p. ct. Shell fragments.	21.5 p. ct. Amorphous carbonate of lime 0.9, quartz 0.1.	40.6 p. ct. Amorphous carbonate of lime and sand, equal proportions.	10.9 p. ct. Amorphous carbonate of lime 0.7, quartz 0.3.	8.7 p. ct. Amorphous carbonate of lime 0.9, quartz 0.1.	8.2 p. ct. Amorphous carbonate of lime, with sponge spicules and diatoms.
17	13.000	14 p. ct. Shell fragments.	18.1 p. ct. Shell and amorphous carbonate of lime sand.	26.7 p. ct. Amorphous carbonate of lime. Quartz rare.	14.7 p. ct. Amorphous carbonate of lime 0.6, quartz 0.4.	10.7 p. ct. Amorphous carbonate of lime 0.75, quartz 0.25.	15.8 p. ct. Amorphous carbonate of lime. Quartz rare, sponge spicules and diatoms.
18	8.840	6.6 p. ct. Shell fragments.	11.2 p. ct. Like 20.	38.1 p. c. Amorphous carbonate of lime sand, some oval grains. Quartz rare.	20.2 p. ct. Like 80.	14.3 p. ct. Amorphous carbonate of lime, mostly oval grains. Diatoms and sponge spicules.	9.6 p. ct. Like 200.
19	3.623	24.4 p. ct. Shells and shell fragments and calcite.	15.9 p. ct. Shell fragments, calcite, quartz rare.	19.6 p. ct. Like 40.	8.5 p. ct. Like 40 but more quartz.	18.4 p. ct. Like 40 quartz rare.	13.2 p. ct. Like 40 but some aragonite, quartz rare.

[1] Specimen contained organic matter.

[2] Like No. 12. (Different sizes not examined separately.)

Table giving results of physical and microscopic examination of sea-bottom materials obtained among Florida Keys.—Continued.

Specimen No.	Weight of sample (grams).	Per cent and description of material retained on 20-mesh sieve.	Per cent and description of material retained on 40-mesh sieve.	Per cent and description of material retained on 80-mesh sieve.	Per cent and description of material retained on 100-mesh sieve.	Per cent and description of material retained on 200-mesh sieve.	Per cent and description of material passing 200-mesh sieve.
20	7.225	53.1 p. ct. Shells and shell fragments.	27.2 p. ct. Amorphous carbonate of lime and quartz equal proportions.	15.8 p. ct. Amorphous carbonate of lime 0.75, quartz 0.25.	1.1 p. ct. Amorphous carbonate of lime with considerable quartz. Sponge spicules and diatoms.	1.2 p. ct. Amorphous carbonate of lime, aragonite. Quartz abundant, sponge spicules and diatoms.	1.6 p. ct. Like 200.
21	9.216	13.6 p. ct. Shell fragments, some quartz.	41.9 p. ct. Chiefly quartz, some shell fragments.	39.5 p. ct. Quartz 0.75, amorphous carbonate of lime 0.25.	3.8 p. ct. Amorphous carbonate of lime, quartz abundant.	0.6 p. ct. Amorphous carbonate of lime. Quartz common. Sponge spicules and diatoms.	0.6 p. ct. Amorphous carbonate of lime, quartz rare, diatoms and sponge spicules.
22	13.000	19.2 p. ct. Shell fragments.	22.2 p. ct. Shell, amorphous carbonate of lime sand, quartz rare, organic matter.	18.4 p. ct. Chiefly amorphous carbonate of lime.	7.7 p. ct. Chiefly amorphous carbonate of lime. Much organic matter. Sponge spicules and diatoms.	17.1 p. ct. Like 100. More organic matter.	15.4 p. ct. Like 200. Much organic matter.
23	4.721	None.	4.1 p. ct. Chiefly organic matter, some amorphous carbonate of lime.	25.7 p. ct. Like 40 but nearly 0.5 amorphous carbonate of lime. Quartz very rare.	17.1 p. ct. Amorphous carbonate of lime and organic matter, sponge spicules and diatoms.	35.6 p. ct. Like 100.	17.5 p. ct. Like 200, sponge spicules and diatoms abundant.
24?	13.000	10.7 p. ct. Shells and shell fragments.	15.3 p. ct. Shells and amorphous carbonate of lime.	29.4 p. ct. Amorphous carbonate of lime. Quartz abundant.	27.2 p. ct. Like 80 with less quartz.	10.8 p. ct. Amorphous carbonate of lime. Sponge spicules and diatoms.	6.8 p. ct. Like 200, some aragonite.
25	13.000	17.3 p. ct. Shells and shell fragments.	17.2 p. ct. Amorphous carbonate of lime. Quartz rare.	30.4 p. ct. Amorphous carbonate of lime. Quartz rare.	8.7 p. ct. Amorphous carbonate of lime. Quartz rare.	11.2 p. ct. Amorphous carbonate of lime.	15.2 p. ct. Amorphous carbonate of lime. Sponge spicules and diatoms.
26	11.373	10.3 p. ct. Shells and shell fragments.	16.2 p. ct. Like 20. Quartz rare.	26 p. ct. Organic matter, sponge spicules and diatoms. Quartz rare.	21.1 p. ct. Like 80.	16.3 p. ct. Like 80 with calcite and aragonite.	10.1 p. ct. Like 200.
27	This specimen was lost.						
28	11.373	58.8 p. ct. Shells and shell fragments.	17.2 p. ct. Shell fragments and amorphous carbonate of lime.	10.9 p. ct. Amorphous carbonate of lime. Quartz rare. Sponge spicules and diatoms.	3.1 p. ct. Like 80 with aragonite.	5.2 p. ct. Like 80 with no quartz.	48 p. ct. Like 200.

Table giving results of physical and microscopic examination of sea-bottom materials obtained among Florida Keys.—Continued.

Specimen No.	Weight of sample (grams).	Per cent and description of material retained on 20-mesh sieve.	Per cent and description of material retained on 40-mesh sieve.	Per cent and description of material retained on 80-mesh sieve.	Per cent and description of material retained on 100-mesh sieve.	Per cent and description of material retained on 200-mesh sieve.	Per cent and description of material passing 200-mesh sieve.
29	13.000	12.8 p. ct. Shell fragments.	6.1 p. ct. Shell fragments and amorphous carbonate of lime.	13.2 p. ct. Amorphous carbonate of lime, aragonite, sponge spicules, and diatoms.	21.2 p. ct. Like 80.	32.6 p. ct. Like 80, quartz very rare.	14.1 p. ct. Amorphous carbonate of lime, calcite, aragonite, diatoms, sponge spicules.
30?	16.000	24.5 p. ct. Shells and shell fragments.	12.2 p. ct. Amorphous carbonate of lime. Calcite.	16.2 p. ct. Like 40. Sponge spicules and diatoms.	13.6 p. ct. Like 80.	18.2 p. ct. Like 80.	15.3 p. ct. Like 80. Aragonite common.
[2]31	13.000	6.4 p. ct. Amorphous carbonate of lime. Quartz rare.	14.6 p. ct. Like 20.	17.6 p. ct. Amorphous carbonate of lime, calcite, and chalcedony.	14.2 p. ct. Like 20. Sponge spicules and diatoms.	28.9 p. ct. Like 100.	18.3 p. ct. Like 200. Aragonite.
[2]32	12.710	5.5 p. ct. Shells and amorphous carbonate of lime.	17.4 p. ct. Like 20, more amorphous carbonate of lime.	22.8 p. ct. Amorphous carbonate of lime, organic matter, diatoms, and sponge spicules.	10.9 p. ct. Like 80.	18.6 p. ct. Like 80.	24.8 p. ct. Like 80. Sponge spicules and diatoms.
33	12.773	3.5 p. ct. Shells and amorphous carbonate of lime.	14.7 p. ct. Amorphous carbonate of lime, largely aggregated.	50 p. ct. Like 40. Less aggregation. Sponge spicules and diatoms.	11.9 p. ct. Like 80.	16.2 p. ct. Like 80.	3.7 p. ct. Like 80.
34	13.000	27.1 p. ct. Shell fragments, amorphous carbonate of lime (aggregated).	40.1 p. ct. Like 20, quartz rare.	19.1 p. ct. Amorphous carbonate of lime 0.25, quartz 0.75, sponge spicules, and diatoms.	3.8 p. ct. Amorphous carbonate of lime. Quartz abundant. Sponge spicules and diatoms.	5.9 p. ct. Amorphous carbonate of lime. Organic matter, sponge spicules, and diatoms.	4 p. ct. Like 200 with calcite.
35	13.000	21.8 p. ct. Shell fragments. Quartz rare.	40.2 p. ct. Amorphous carbonate of lime. Quartz rare.	18.5 p. ct. Amorphous carbonate of lime. Quartz.	6.6 p. ct. Amorphous carbonate of lime. Some oval grains. Quartz very rare. Sponge spicules and diatoms.	8.7 p. ct. Amorphous carbonate of lime, calcite, diatoms and sponge spicules.	4.2 p. ct. Like 200.
36	13.000	14.7 p. ct. Shell fragments. Amorphous carbonate of lime.	46.1 p. ct. Shell sand and amorphous carbonate of lime.	17.3 p. ct. Chiefly calcite. Quartz rare. Diatoms and sponge spicules.	3.1 p. ct. Like 80.	13.4 p. ct. Like 80 but no quartz.	5.4 p. ct. Amorphous carbonate of lime, calcite, aragonite, diatoms and sponge spicules.
37	13.000	14.9 p. ct. Shells and shell fragments. Amorphous carbonate of lime.	24.9 p. ct. Shell fragments. Amorphous carbonate of lime and a few oval grains.	25.6 p. ct. Like 40. Quartz rare.	12.3 p. ct. Like 80 with sponge spicules and diatoms.	16.6 p. ct. Like 100.	5.7 p. ct. Like 100.

[2] Lime aggregated; disaggregates when wet

Table giving results of physical and microscopic examination of sea-bottom materials obtained among Florida Keys.—Continued.

Specimen No.	Weight of sample (grams).	Per cent and description of material retained on 20-mesh sieve.	Per cent and description of material retained on 40-mesh sieve.	Per cent and description of material retained on 80-mesh sieve.	Per cent and description of material retained on 100-mesh sieve.	Per cent and description of material retained on 200-mesh sieve.	Per cent and description of material passing 200-mesh sieve.
38?	7.720	39.2 p. ct. Shells and shell fragments.	23.9 p. ct. Like 20 with amorphous carbonate of lime.	18.4 p. ct. Amorphous carbonate of lime. Some crystalline material.	8.8 p. ct. Like 80.	8.1 p. ct. Like 80. Quartz rare.	1.5 p. ct. Amorphous carbonate of lime.
39?	13.000	13.5 p. ct. Shell fragments.	22.7 p. ct. Amorphous carbonate of lime.	23.4 p. ct. Amorphous carbonate of lime. Chalcedony.	9.3 p. ct. Like 80.	16.9 p. ct. Like 80 but no chalcedony, sponge spicules and diatoms.	14.2 p. ct. Like 200.
40	13.000	32 p. ct. Shell fragments. Amorphous carbonate of lime.	42.4 p. ct Shell fragments, a few oval grains.	14.8 p. ct. Like 40 with organic matter and calcite.	3.4 p. ct. Quartz rare. Amorphous carbonate of lime, organic matter, calcite. Diatoms and sponge spicules.	4.2 p. ct. Like 100 but no quartz.	3.2 p. ct. Like 200.
41?	13.000	27.6 p. ct. Shell fragments.	29.4 p. ct. Amorphous carbonate of lime, calcite.	14.4 p. ct. Like 40, quartz rare.	7.1 p. ct. Like 80.	6.7 p. ct. Like 80. Sponge spicules and diatoms.	14.8 p. ct. Like 200.
42	13.000	10.6 p. ct. Shells and shell fragments.	30.5 p. ct. Shell fragments and amorphous carbonate of lime.	20.7 p. ct. Like 40, quartz very rare. Sponge spicules and diatoms.	8.4 p. ct. Like 80. Calcite.	11.9 p. ct. Like 100, aragonite.	7.9 p. ct.
43	9.175	11.6 p. ct. Shells and shell fragments.	54.2 p. ct. Shell fragments and amorphous carbonate of lime.	25.6 p. ct. Lime, many oval calcite grains.	1.9 p. ct. Like 80. Quartz rare.	2 p. ct. Like 100.	4.7 p. ct. Like 100, aragonite.
44	13.000	17.8 p. ct. Shell fragments. Amorphous carbonate of lime.	38.3 p. ct. Like 20.	16.4 p. ct. Amorphous carbonate of lime. Sponge spicules and diatoms.	13.8 p. ct. Like 80.	9.2 p. ct. Like 80.	4.5 p. ct. Like 80.
45	13.000	19.6 p. ct. Shells and shell fragments.	33.2 p. ct. Shells and shell fragments.	21.3 p. ct. Amorphous carbonate of lime. Oval grains, quartz rare.	10.2 p. ct. Like 80.	12.6 p. ct. Amorphous carbonate of lime. Some oval grains.	3.1 p. ct. Like 200. Sponge spicules and diatoms.
46	13.000	27.9 p. ct. Shells and shell fragments.	33.4 p. ct. Like 20, some oval grains.	22.4 p. ct. Amorphous carbonate of lime. Oval grains. Quartz rare.	5.9 p. ct. Like 80.	5.6 p. ct. Amorphous carbonate of lime. Some oval grains. Sponge spicules and diatoms.	4.8 p. ct. Like 200.
47	13.000	19.4 p. ct. Shell fragments, amorphous carbonate of lime.	25.1 p. ct. Like 20.	24.8 p. ct. Amorphous carbonate of lime. Quartz very rare.	15.2 p. ct. Amorphous carbonate of lime. Sponge spicules, diatoms.	11.7 p. ct. Like 200. calcite.	3.8 p. ct.

SOURCES OF MATERIAL.

Table of Geologic Formations in Florida.

	Period.	Group.	Formation.		Lithologic description of the formation.
Quaternary	Recent				Human remains. Vermetus rock. Beach sands. Coquina. Aeolian deposits. Lacustrine deposits. Chemical deposits. Alluvial deposits.
	Pleistocene				Yellow sand. "Vermetus rock." Coquina. "Planorbis rock." Gray sand. Fossiliferous marls.
			Palm Beach Limestone......		Light-colored limestone with sandy beds and loose sand.
			Miami oolite................		Light-gray to white oolitic limestone, sandy in places.
			Key Largo limestone........		Coral limestone; reef rock.
			Key West oolite.............		Light-gray to white oolitic limestone.
			Lostman River limestone....		Dark to light, hard to friable, limestone, sandy or marly in places.
			Unconformity		
Tertiary	Pliocene		Lafayette..............	Largely contemporaneous deposition	Clay and sand with some pebbles, color usually red or yellow.
			Bone Valley gravel.....		Light-colored gravel and marl, containing phosphatic pebbles.
			Alachua clay..........		Greenish sandy clay, weathering yellow or red.
			Nashua marl..........		Light-colored sandy shell marl.
			Caloosahatchee marl....		Light-colored sandy shell marl.
			Unconformity (?)		
	Miocene		Jacksonville formation (East Coast)	Contemporaneous deposition	Light-gray to white limestone weathering light yellow. Light gray to yellow clay and gray sand. Some chert beds.
			Choctawhatchee marl (West Florida and St. John's Valley)		Greenish to light-gray sandy shell marl or greenish gray clay.
			Unconformity		
	Oligocene	Apalachicola Group	Alum Bluff formation.......		Gray to green sands, clays and fuller's earth. Limestone occurs in some localities but it is usually impure.
			Chattahoochee formation (West Florida)	Largely contemporaneous deposition.	Light-yellow to gray earthy and siliceous limestones, sometimes cherty. Sand and clay rare.
			Hawthorne formation (Central Florida)		Yellow limestones, often phosphatic. Greenish or reddish sands. Green clays.
			Tampa formation (South Florida)		Yellow limestone and greenish clays. Some chert nodules and layers.
			Unconformity		
		Vicksburg Group	Ocala limestone............		Soft, porous, light-gray to white limestone with beds of marl and layers of chert.
			Peninsula limestone (Central Florida)		Soft, porous, light-gray to white limestone containing marl beds and layers of chert.
			Marianna limestone (Western Florida)		Soft, porous, light-gray to white limestones containing some marl and more rarely clay beds. Layers of chert common.

SILICA.

The presence of siliceous sand in the northern portion of Biscayne Bay is accounted for by similar material overlying the Miami oolite in the adjacent regions, and by the streams emptying into the bay mechanically removing to it a portion of the deposit. The sand of southern Florida has attracted the attention of a number of geologists, among them Professor Shaler and Mr. A. Agassiz. The material must have been derived from the continental masses to the north, but the various factors by which it was brought so far south have not been thoroughly understood.

GEOLOGIC DISTRIBUTION OF SILICEOUS SAND IN FLORIDA.

Until recently the amount of sand in the geological formations underlying the surficial Pleistocene deposits was not known. Therefore it may be interesting in this connection to outline the geologic history of arenaceous deposits in Florida. The table of geologic formations on the preceding page is taken, with some verbal changes, from "A Preliminary Report on the Geology of Florida, with special reference to the stratigraphy, by George Charlton Matson and Frederick G. Clapp, including a chapter on the Topography and Geology of Southern Florida by Samuel Sanford." [1]

In northern Florida the following geologic formations older than the Pleistocene contain sand beds:

Pliocene: Lafayette formation, Alachua clay, Nashua marl, Caloosahatchee marl.
Miocene: Jacksonville formation, Choctawhatchee marl.
Oligocene: Alum Bluff formation, Hawthorne formation.

In the northern portion of the State formations of every period from the Oligocene to the Recent contain deposits of sand. It should be stated, however, that no predominantly sand beds have been reported from the Vicksburgian Oligocene, although the formations of that group contain some sand and silica of organic origin.

In southern Florida sand of Pleistocene and post-Pleistocene age is generally known to be present, at least as far south as Miami. The three following well records extracted from Mr. Sanford's chapter in the report on the stratigraphic geology of Florida will indicate its distribution in preceding geologic periods:

Partial record of well of C. I. Craigin, Palm Beach.

Description.	Feet.	
Sands with thin layers of semi-vitrified sand at 50 and 60 feet	0 to	400
Very fine-grained soft greenish-gray quartz sand, containing occasional foraminifera and water-worn shell fragments	400	800
White sand with abundant foraminifera of four or five species	850	860
Gray sand, containing shark's teeth, small water-worn shells and bone fragments, sea-urchin spines, and lithified sand fragments	904	915
Samples at frequent intervals, Vicksburg limestone containing Orbitoides in abundance throughout, together with occasional indeterminable fragments of molluscan casts, corals, and echinoderms. It is a creamy white, hard, homogeneous limestone throughout	1,000	1,212

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[1] Prepared in coöperation between the United States Geological Survey and the Florida State Geological Survey, under the direction of Thomas Wayland Vaughan, Florida Geol. Surv., 2d Ann. Report, 1910.

Darton was unable to determine definitely the age of the series overlying the limestones, but the organic remains from 800 to 915 feet suggested Miocene age, while foraminifera between 400 and 800 feet indicated that the beds whence they came are also probably of Miocene age.

This record shows that the top of the Vicksburg group (Lower Oligocene) lies between 915 and 1,000 feet below the surface at Palm Beach. The great thickness of quartz sands is the most noteworthy feature of the record.

Key Vaca.—Two wells were sunk at Marathon, Key Vaca, one reaching a depth of 435 feet, the other 700 feet. The combined records of the two wells gives the following section:

Record of wells of Florida East Coast Railway, Marathon.

Description.	Feet.	
Reef rock	0 to	105
Hard to soft white limestone, with much white marl	105	148
Soft white limestone with shell casts	148	150
Medium hard white limestone, shell casts and shell fragments	150	155
Soft white limestone with quartz grains, proportion of quartz increasing with depth, shell fragments and casts	155	176
Medium fine white quartz sand containing numerous irregular nodules, with yellowish marly sand at 210 to 215 feet	176	230
Quartz sand in a varying proportion of limy mud, sand grains colorless, mud yellowish to dark green; streaks and beds of friable sandstone containing shell casts; bed of oyster shells at 240 feet	230	300
Quartz sands or beds of soft, friable sandstone containing shell casts; streaks of dark green limy clay, 306 to 310 ft.; beds of shells, few determinable fossils, probably Miocene, 378 to 390	300	400
Quartz sands as below 230 feet; beds of soft friable sandstone with shell casts; gravel bed with much worn pebbles up to 40 mm. long; tough green limy clay, at 407 to 410 feet	400	435
Quartz sands with little sandstone, tough dark clay in occasional streaks	435	700

While the many samples of drillings from this well show the lithology of the formations penetrated, they give much less satisfactory evidence as to geologic age. The sands below 176 feet yielded but a small variety of determinable fossils. An occasional claw or carapace of a small crab or a few barnacle plates were the only organic remains noted in going through many feet of sand. The friable sandstones contained many casts, internal and external, of pelecypod shells, the external casts being of sandstone, the internal of more clayey material. These casts, while numerous, were not sharp enough to be of diagnostic value.

The shell beds yielded a small variety of species. T. Wayland Vaughan identified five species, including pectens and an oyster, which were probably Miocene, from collections between 375 and 420 feet.

Thus the Key Vaca section, while it shows limestone, Pleistocene, and sands probably Pliocene, gives no data for separating Pliocene from Miocene. The coarseness of the sands, their barrenness and the character of the few determinable fossils between 176 and 400 feet indicate shoal water and strong currents. No break in deposition is determinable.

Fossils from Marathon Well, Key Vaca, were identified by T. W. Vaughan, as follows:

Depth 375 to 400 feet: Turritella variabilis Conrad; *Ostrea,* apparently a new species; *Pecten* sp. fragment, probably *P. madisonius* Say; *Pecten* sp. fragment, very near *P. humphreysi* Conrad; *Pecten* sp. young, apparently *P. eboreus* Conrad.

Geologic Horizon: Although the number of species is small, and positive specific identification can be made in only one instance, the fauna has a distinctly Miocene facies. The series of Pectens represented by *madisonius*, *humphreysi*, and *eboreus* occur in association only in the Miocene.

The matrix of these fossils is light olive-green quartz sand with some calcareous material. A few oolitic granules are present. Similar material continues to 640 feet, becoming coarser at the lower levels. Between 620 and 640 feet there are quartz pebbles 0.375 inch long.

Depth 640 *to* 660 *feet: Orbitolites complanata* d'Orb.; *Stylophora* sp.; *Porites* sp.

Geologic Horizon: Apalachicolan Oligocene. The matrix is a whitish limestone in which are small cavities.

Depth 680 *to* 700 *feet: Pecten* fragments, probably *P. perplanus* Morton.

Geologic Horizon: Not definitely determinable, but Vicksburgian Oligocene is suggested.

A record of the Buck Key well (of W. H. Knowles) given from memory by the driller, James Sykes, supplemented by samples saved at odd depths, furnishes the following section:

Description.	Feet.	
Sand and shells	0 to	50
Brown crystalline limestone with cherty streaks and sand grains	50	60
White quartz sand, with marl and shell fragments	60	63
Brownish sandy limestone with shell fragments	63	65
Dark greenish marl	65	145
White quartz sand, with shell bed at 150 feet	142	275
Medium dark greenish marly sand, with shell beds, and streaks of lighter marl	275	490
White to brownish, and soft to hard, limestone, with a few shell casts; hard brownish limestone contains many siliceous grains	490	605

The correlation of the geologic formations penetrated in these wells is a difficult matter, but we know sand is abundant below 155 feet in depth on Key Vaca and we may be confident that Pliocene and Miocene sands extend as far southward as that key. The quantity of siliceous material contributed to southern Florida appears to have reached its maximum in the Miocene period and since then to have diminished interruptedly. The Pleistocene limestones of the mainland rest on an arenaceous foundation.

The presence of Miocene sands as far south as Key Vaca possesses a geologic interest in that they indicate that the great Floridian platform existed in Miocene times, and that sand which must have come from the north, as no southern source is known, was being carried to that region during that period.

Silica derived from sponge spicules and diatoms is universally present in the near-shore marine deposits, but not in sufficient quantity to form of itself important deposits.

CALCIUM CARBONATE.

The origin of the material of the calcareous deposits presents a more complicated problem than that of the siliceous. Its source is both inorganic and organic.

CALCIUM CARBONATE OF INORGANIC ORIGIN.

The calcium carbonate is derived through two inorganic agencies: chemical denudation and erosion. In order to understand both the sources and the means by which the material is transported to the ocean, it will be necessary briefly to consider the geologic formations, topography, vegetation, drainage, rainfall, and surface run-off of the land areas.

PLEISTOCENE LIMESTONES OF SOUTHERN FLORIDA.

The whole of the surface of southeastern Florida is either formed or underlain at no great depth by a series of limestones, all of which are of Pleistocene age. The more important of these formations will be described in the succeeding paragraphs.

The Miami oolite, named from the city of Miami, is a soft, white or cream-colored, oolitic limestone breaking with an irregular fracture and containing streaks of thin, irregular layers of calcite (plate 13, fig. *b*). The rock is quarried as a building stone in the vicinity of Miami, and as it hardens on exposure it serves its purpose well. Spheroidal oolite grains are its most important constituent. The diameter of the granules ranges from less than 0.5 mm. to a little over 1 mm. Mr. Sanford, who has studied the granules microscopically, says:

> Examination with the microscope shows that the ovules have a well-marked concentric structure; the nucleus of some ovules is a rounded aggregate of minute calcite crystals, of others a rounded aggregate less evidently crystalline; sometimes the nucleus is a shell fragment and frequently it is a grain of quartz. The concentric layers vary in number from 1 to 4 or 5, and in appearance from clear and rather coarsely crystalline to opaque. The layers are darker or lighter from varying amounts of organic matter and amorphous material.

The oolites are embedded in a cement of amorphous or crystalline calcium carbonate, and there is some sand. The latter material is more abundant at the north and decreases southward; there is also a slightly greater proportion of sand along the eastern outcrop than toward the west. This formation has a maximum thickness of perhaps 50 feet. Its areal extent is southward from the vicinity of Del Ray to 10 or 12 miles beyond Homestead, and westward it forms the floor of the eastern portion of the Everglades.

The Lostman River limestone, named by Mr. Sanford from its typical occurrence along Lostman River, is a non-oolitic Pleistocene limestone of varying physical characters; in some places it is hard, largely made up of crystalline calcite; in others, soft and friable. At the head of Henderson Creek it contains considerable sand. Its thickness is said by Mr. Sanford to be 30 feet at Everglade and over 40 feet at the mouth of Shark River. It underlies the shore of the mainland from Jewfish Creek westward and northwestward to near Marco, extends some miles to the north of the last-mentioned place, and to the northeast passes beneath the great swamps of the interior.

The Key Largo limestone is the elevated coral-reef rock forming the main line of keys from Soldiers Key to the southern end of Big Pine Key. Its name was taken from Key Largo because of the excellent exposures recently made there by the excavations along the line of the Florida East Coast Railway extension. The most conspicuous component of this formation is coral, usually in the form of large heads of *Mæandra* and *Orbicella* (plate 15, figs. *b* and *c*). The interspaces are filled with various kinds of calcareous débris derived from marine organisms. Over the surface there is frequently a hard crust composed of colored, laminated, amorphous calcareous material. The lime of the coral heads is frequently crystalline.

These three limestones are the principal geologic formations surrounding the bays and sounds of southeastern Florida. Toward the interior of the State, however, both the Miami oolite and the Lostman River limestone are overlain by the great interior swamp deposits, the most extensive and famous of which are the Everglades.

There is in this region another important limestone formation, the Key West oolite, which closely resembles the Miami oolite in appearance (plate 14, figs. *b* and *c;* plate 15, fig. *a*). It is a soft, white or cream-colored limestone, mostly composed of oolitic granules embedded in a loose matrix of amorphous, or occasionally crystalline, calcium carbonate. The structure of the granules of the two is the same, except silica is rarer in the Key West oolite. The thickness of this formation is unknown, but is tentatively placed by Sanford at 50 feet. It is the rock composing all the keys from No Name and Little Pine to Boca Grande, except the purely mangrove keys.

Although the Key West and Miami oolites are so similar and may be geologically contemporaneous, they are not known to be in contact anywhere, as both the Key Largo and Lostman River limestones intervene between their respective outcrops.

TOPOGRAPHY OF SOUTHERN FLORIDA.

The whole of the area under consideration is one of low relief, the greatest elevation known being perhaps 30 feet. The Miami oolite forms a limestone ridge extending southward from the vicinity of Del Ray to beyond Homestead. The elevations along this ridge are about 8 feet at New River, Fort Lauderdale; perhaps 30 feet south of Miami, and about 8 feet on Long Key in the Everglades. In the vicinity of Miami there is a steeper sea-face with a westward slope, the rock passing beneath and forming the floor of the Everglades. The width of this ridge west of Miami is about 3 miles.

The Everglades are a vast interior swamp, the surface of which is mostly an enormous saw-grass marsh with mottes of timber here and there breaking the monotonous expanse. The altitude is almost the same as that generally prevalent over this section of the State. Some determinations along the eastern margin are: "west of Lantana, 18 feet; west of Hillsboro Inlet, 14 feet; west of Fort Lauderdale, 17 feet; at the pool at the head of Miami River, 6.2 feet. South of the Biscayne pineland and Long Key the height of the Everglades is less than 6 feet" (Sanford). The maximum elevation of the keys east of Key West perhaps does not exceed 5 or 6 feet.

VEGETATION OF SOUTHERN FLORIDA.

The vegetation of the area presents three different types. The oolite ridge is mostly covered by pines, the soil is thin and the surface of the ground rocky (plate 8, fig. *a*); in the Everglades (plate 7, figs.

c and *d*) there is a growth of saw-grass and an accumulation of vegetable muck of varying depth—in some places thin, merely a surface veneer; in others 4 or 5 feet, or perhaps even more, in depth. The interior of the keys is usually a jungle, while often, but not invariably, mangroves fringe the water front (plates 9, 10, 11, and 12, fig. a).

DRAINAGE AND RAINFALL OF SOUTHERN FLORIDA.

Southeastern Florida is a very poorly drained country. There are comparatively few streams leading from the interior swamp to the sea. A small river at Miami, known as Miami River, leads from the Everglades to Biscayne Bay. Another, Taylor River, empties into Florida Bay in southern Dade County. However, a large proportion of the waters of the interior works its way to the ocean, as there is a general southward movement of the waters of the Everglades. There is in the vicinity of Miami and also along the keys direct surface run-off from the landmass into the ocean.

The rainfall for this section of Florida, according to Gannett,[1] is between 60 and 70 inches per annum.

No accurate records have been kept of the surface run-off of the streams and from the swamps of southern Florida. Therefore any figure given must be derived by applying the results obtained in other areas and making allowance for peculiar conditions prevailing in this region. Mr. J. C. Hoyt, in his "Comparison between Rainfall and Run-off in the Northeastern United States," makes the statement:

> The run-off is very consistent in the various groups, and decreases toward the south, although the rainfall increases. It is about 60 per cent of the precipitation in the northern areas, 55 per cent in the intermediate areas, and 40 per cent in the southern areas. This decrease in run-off is due to the increase in evaporation and the loss by vegetation, and shows that the climate and vegetation are probably the principal regulating factors in the relation between rainfall and run-off.
>
> * * * * * * *
>
> The climatic conditions are responsible for this change in the percentage of run-off between northern and southern areas, rather than geologic conditions or topography, as is shown in the "percentage" column for the summer months, where the percentage of run-offs varies between 20 and 32, having a mean of 27 per cent for all principal basins. This column shows no regular variations for the basins. It also shows that the evaporation and loss through evaporation is very nearly the same over the various areas considered, being about 9.5 inches. (American Society of Civil Engineers, Transactions, vol. 49, p. 436.)

As the temperature of southeastern Florida is never lowered to the freezing-point and as there is a luxuriant vegetation, it is probable that the lowest estimate of run-off given by Mr. Hoyt, 27 per cent, is slightly too high. Therefore 25 per cent[2] is taken as a more probable figure; and the annual run-off for this area is estimated as 25 per cent of 60 inches, or 15 inches.

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[1] U. S. Geol. Surv., Water Supply Paper 234.

[2] Mr. J. O. Wright, Drainage Engineer, U. S. Department of Agriculture, by a somewhat different process, arrived at the same estimate for the percentage of surface run-off in southern Florida. (Report of the Special Joint Committee of the Legislature of Florida on the Drainage of the Everglades of Florida, pp. 25–29, Tallahassee, 1909.)

The area of Dade County, from which the surface run-off is into the bays and sounds behind the keys, is approximately 1,840 square miles. The surface run-off from this territory would be approximately 0.52 cubic mile per annum. This amount, however, ought to be increased as the waters from Lake Okeechobee and the Everglades move southward, and a portion of them apparently must flow to the southeast. As is well known, a considerable portion of the territory to the north of Lake Okeechobee is drained into that basin and the water is discharged through the rivers leading to the west, east, southeast, and south of the Lake or the Everglades. Therefore the discharge into the bays and sounds is probably between 1.0 and 0.5 cubic mile.

CHEMICAL DENUDATION.

Having given in the preceding remarks the physical surroundings of the bays and sounds, and given an estimate of the surface run-off of the waters, the chemical denudation of the region may be discussed. That chemical denudation is active in southeastern Florida is attested by numerous phenomena. The surface of the Miami oolite is extremely irregular; some irregularities are due to rocks torn from the general oolitic mass by uprooted pine trees, while others are produced by the solvent effect of water, as is especially well shown by small sink-holes, pot-holes, and such phenomena as the Arch Creek natural bridge. According to Mr. Sanford:

> The holes, which communicate with underground solution channels, are of all sizes, varying from those not over an inch across to those 20 feet or more in diameter. Their depths range from 3 to over 10 feet. Besides the sharply outlined holes, there are throughout the pineland countless shallow hollows 1 to 3 feet deep and 10 to 100 feet across. A few of these hollows may owe their origin to original conditions of deposition, some may be due to the overturning of trees and consequent upheaval of the rocks loosened by roots, while others have been caused by the falling in of the roofs of subterranean water-courses. Few of the holes and hollows are large enough to be termed sinks. The large vertically walled holes running down to permanent water-level form natural wells, the shallow hollows are best denominated pot-holes. The writer has heard of only one rock-rimmed opening in southern Florida that resembles the great sinks in the country to the north.
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> * * * * * * *
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> While there is danger of exaggerating the activity of underground and surface water in eating away the soft limestone of the east coast, yet there is plentiful evidence of solution. The pot-holes and the hollow-sounding areas of rock, perhaps 25 feet across, with as many as 6 or 7 holes a foot or so in diameter showing the water beneath, that are found along the edges of the southern Everglades, the springs below tide-level at Cocoanut Grove, and other points on the shore of Biscayne Bay, the Punch Bowl, a spring basin, the deep holes in New River, and the shallow gorge of Arch Creek with its low rock bridge, all bear witness to the work being done.

The conditions favorable for vigorous chemical denudation of limestone are: (1) a supply of water charged with CO_2; (2) the water remaining in contact with limestone a sufficient time to permit solution; (3) having dissolved lime to be able to move onward.

Conditions favorable for such denudation are largely realized in southern Florida: there is limestone; the waters become charged with carbonic-acid gas from passing over large areas of decaying vegetable matter; and, as the flow toward the sea is gentle, there is opportunity for the dissolving acid to act on the limestone. Over a considerable area in the Everglades, although limestone underlies the surface material, the water is prevented from coming in contact with it. Therefore, most of the solution must be accomplished on the higher region of the Miami oolite and the coastal fringe of the Lostman River limestone. There is also chemical denudation on the Key Largo limestone and Key West oolite of the keys. The following quotation from Dr. Sellards is appropriate in this connection:

> Among these agencies of erosion, underground water has acted in Florida under exceptionally favorable conditions. In areas of considerable slope, and with relatively impervious formations, the surface run-off is large. Under these conditions those features of topography determined by the rapid downward cutting of the surface streams and their tributaries predominate. In Florida the surface slope is slight. The open nature of the soil and rock permits the greater part of the water to enter the earth, establishing subterranean rather than surface drainage. The rocks are prevailingly calcareous and soluble. Under these conditions the work of the underground water predominates over surface erosion. In central Florida the topography, soil, and general surface features are determined to a large extent by the work of underground water.
>
> Solution is the most apparent, and geologically the most important result of underground water circulation. Rainwater, while passing through the air, takes into solution a small amount of CO_2 gas. To this is added organic and mineral acids taken up while passing through the soil. Increased pressure, as the water descends into the earth, enables the water to hold in solution greater quantities of gases, acids, and salts, all of which greatly increase the dissolving power of the water.
>
> That underground water is efficient as a solvent is evident from the analyses of well and spring waters. Rainwater entering the earth with almost no solids in solution returns to the surface through springs and wells with a load of mineral solids in solution determined by the length of time it has been in the ground, the distance traveled, and the character of the rocks and minerals with which it comes in contact.
>
> The mineral matter thus taken into solution is carried along with water, and while some of it is redeposited, a large amount is removed annually. An estimate of the total mineral solids thus removed is difficult. A conception of the largeness of the amount removed is obtained from a consideration of some of the individual springs.
>
> The water of Silver Springs contains, as shown by analysis, 274 parts solids per 1,000,000 parts water. Otherwise expressed, each 1,000,000 pounds of water is carrying with it 274 pounds of solids in solution. Silver Spring is estimated to flow a little more than 3,000,000 pounds of water per minute (368,913 gallons). The interior of Florida is thus being carried into the ocean through Silver Springs at the rate of more than 340 pounds per minute or about 600 tons per day.
>
> The total solids removed in solution through 6 other springs of central Florida, expressed in tabular form, gives the following results:

Name of spring.	County.	Total solids parts per 1,000,000.[1]	Estimated flow (gallons per minute).	Solids removed (pounds).
Blue	Marion	112.1	349,166	469,698
Blue	Levy	196.8	25,000	59,040
Ichatucknee	Columbia	311.6	180,000	457,056
Newland	Suwanee	233.5	75,000	210,150
Weekiwachee	Hernando	227.8	100,000	273,360
White Sulphur	Hamilton	166.6	32,400	64,744
Suwanee	Suwanee	332.7	52,000	207,605

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[1] Organic matter is deducted from the total solids as given for Suwanee Sulphur and White Sulphur Springs. The organic matter occurring in the other springs is of small amounts and was not separately determined.

As the basis of an estimate of the total solids removed annually from the interior, let it be assumed: (1) that the average total solids in spring water amounts to as much as 219 parts per 1,000,000, this average being obtained from 8 of the typical large springs of central Florida; (2) that the annual escape of the underground water approximates the annual intake, amounting, as previously estimated (p. 16), to 460,536,689 gallons per square mile. Upon these estimates the mineral solids removed amount to a little more than 400 tons annually per square mile.

Of the minerals thus removed, calcium carbonate or limestone greatly predominates, exceeding the combined weight of all other minerals. From the analyses it appears that magnesium carbonate, magnesium and calcium sulphates are present in variable, although usually limited quantities. Chlorides are normally present in small amount, although occasionally, as in the case of Perrian Spring, they are exceptionally high. Silica is present in amounts varying from 5 to 25.5 parts per 1,000,000. Traces of phosphoric acid and of iron and alumina are usually present.

The several undetermined factors which enter into the above estimates of mineral solids removed make it difficult to formulate a concrete statement of the rate of lowering of the general surface level. Nevertheless, such statements are desired and have a comparative value. Assuming for the rock removed, most of which is limestone, an average specific gravity of 2.5, a layer a foot thick over a square mile should weigh about 2,166,666 tons. The calculated rate of removal of this rock is about 400 tons per square mile per year. From these estimates it would appear that the surface level of the central peninsular section of Florida is being lowered by solution at the rate of a foot in 5,000 or 6,000 years. (Preliminary Report on the Underground Water Supply of Central Florida, Florida Geol. Surv., Bull. No. 1.)

When an attempt is made to estimate the amount of calcium carbonate borne into the sea by the waters of southeastern Florida, the difficulty is immediately encountered of no analytical records having been kept of the waters; therefore any estimate must be based upon a comparison with other regions, and the result obtained in those regions is of doubtful applicability to the one under discussion. Sir John Murray[1] averaged the analyses of 19 rivers and obtained the result that 326,710 tons of $CaCO_3$ per cubic mile of water were discharged into the ocean. The quantity per cubic mile in southeastern Florida may be somewhat greater. Therefore it is suggested that the amount of this material poured annually into the bays and sounds of this region may be between 400,000 and 500,000 tons, or about $\frac{1}{2500}$ of a cubic mile of limestone. This amount of material spread over the floor of the bays and sounds after a considerable proportion has drifted seaward would give only a thin coating for each year.

PRECIPITATION OF CHEMICALLY DISSOLVED CALCIUM CARBONATE.

The problem of the precipitation of the $CaCO_3$ in solution after it has been carried into the sea presents itself. The only definitely known process by which this may be accomplished is by the expulsion of the CO_2. This may be brought about by several methods: it may be driven off by the heat of the sun, it may be lost by the agitation of the waters, or extracted by marine plants. As it is not likely that the surface of the sea is heated to a higher temperature than that of the land, mechanical agitation and the action of marine plants are considered the most probable causes of precipitation in Florida waters.

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[1] Scottish Geograph. Mag., vol. III, pp. 76, 77, 1887.

In the shallow waters near the shore the opportunity for re-solution as the material settles to the bottom is not afforded and the accumulation on the sea-bottom of large quantities of amorphous calcium carbonate, apparently not of detrital origin, is undeniable. The series of samples collected between Miami and Big Pine Key is evidence of this, and additional evidence was obtained by the examination of the surfaces of numerous banks.

One bank about 2 miles northeast of Pigeon Key and another, the shoal west of the upper end of Long Island, have been built nearly to the surface of the water, and are composed of loose calcareous ooze into which I sank while attempting to walk on them to my knees or slightly deeper. An oar could be pushed an undetermined number of feet into the material. Mr. Sanford informs me that a rod can be forced down 10 feet or more. In fact, the depth of this soft material has not been determined.

WHITE-WATER PERIODS.

The white-water periods in the Floridian region are famous. One of the early descriptions of them was given by Captain Hunt.

> The tidal currents set strongly across the reef and through the channels between the keys, the flood running to the north and the ebb to the south side of the key crescent. When storms occur, the agitation of the waves extends to the bottom, over the shallower portions of the grand Bank, and stirs up the sand violently. This causes the water to take up and maintain in mechanical suspension such finely comminuted particles as have too little sinking force rapidly to reach the bottom again. The finer the particles the longer will they remain suspended, and the very coarse grains will hardly be lifted from the bottom. Between the coarsest and finest are grains of all intermediate sizes, and whether they will be suspended or not depends on the violence of the storm, and their interval of suspension varies with their size and the violence of the waves. It results that, in all storms of much violence, the water over the Florida Bank becomes white with the bottom deposits. In long, severe northers or gales, the water becomes almost milk-white across the whole Bank. This "white water" is a familiar appearance, and is one of the sure signs of proximity to the reef. As storms subside, the white sand and mud are gradually thrown down, and the water clears, after a day or two, to its peculiarly delicate transparency. (Am. Jour. Sci., 2d Ser., vol. 35, p. 200, 1863.)

EFFECT OF SEA-SPRAY.

So far the only kind of chemical denudation considered is that resulting from the surface run-off of rainwater, but there is another kind operative around a considerable portion of the south Florida shores. This is corrosion by waves and sea-spray beating on limestone ledges. Very good instances of this kind of corrosion are seen on the western face of Gun Key, Bahamas, and illustrations from photographs are shown on plate 8, figs. *b* and *c*. There are at present no means of estimating the amount of $CaCO_3$ derived in this way, but it is probably considerable.

CALCIUM CARBONATE DERIVED THROUGH SURFACE EROSION.

A considerable portion of the Miami oolite is soft and more or less pulverulent. The detachment of masses from the surface by uprooting due to falling trees, etc., furnishes an opportunity for running water to wash away considerable quantities of limy matter. A portion of this, of course, is washed into the sea in suspension, where it is precipitated on the bottom, increasing the quantity of the calcareous sediments.

Another possible source of material is the region north of the west coast of Florida Bay. Various streams, namely Caloosahatchee River, a number of smaller streams emptying into the Gulf in the vicinity of Thousand Islands, and others further south, cross areas underlain by strata containing more or less lime. A portion of these waters may work their way southward into Florida Bay and contribute to the supply of sediment for that region.

CALCIUM CARBONATE OF ORGANIC ORIGIN.

A large proportion of the calcium carbonate of this region is of organic origin. This is shown by the number of tests of various animals found in almost any dredge haul, and those washed ashore, particularly after storms. The principal constituent of this material is furnished by marine mollusks. Foraminifera are important, as along the shores of the keys one of the commonest organisms is *Orbiculina adunca.* Corals have contributed to the calcareous material, but they are not very abundant within the main line of the reefs and behind the keys. The region between the keys and the main Florida shore is decidedly different from that further to the west represented by the Marquesas and the Tortugas. The limestone composing these two groups is very likely almost entirely of organic origin. On the Tortugas, although corals contribute a large proportion of the calcium carbonate, it appears that they are probably secondary in importance to the mollusks. The breccia on Loggerhead Key is largely formed of wave-tossed molluscan shells.

Two additional sources may furnish calcareous sediment to the bays and sounds. The first is one to which attention was first called by Captain Hunt,[1] whose view was advocated by Mr. Agassiz in his "Three Cruises of the Blake" (p. 57).

As the prevailing direction of the winds and waves, both of trade and hurricane origin, upon the Florida reef is from northeast to southeast, they tend to pick up and carry behind the keys the loose sediment previously prepared by the pounding of breakers; and sediment once having lodged behind there is not likely all to be transported back to the sea by the ebbing of the tides, although, as will be shown later, the outward flowing tidal currents in some instances build deltas at the seaward end of passages between keys.

The general character of coral reefs and the effect of the waves in comminuting pieces of coral or the shells of other organisms have been so frequently and fully described that it is superfluous to furnish a description here.

RÉSUMÉ OF SOURCES OF CALCAREOUS SEDIMENTS.

Reviewing the sources of the calcareous sediment poured into the bays and sounds we find:

(1) That from the mainland and keys surrounding them. This material is derived both by chemical denudation and mechanical erosion.

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[1] Am. Jour. of Sci., 2d Series, vol. 35, p. 202, 1863.

(2) The calcareous remains of organisms living in the waters.
(3) Detrital material washed behind the keys from the reefs and flats lying outside of them.
(4) Some material may be brought southward along the west coast of Florida.

At present data are not available for determining the proportion due to each one of these sources.

GEOLOGIC DISTRIBUTION OF LIMESTONE IN FLORIDA.

It may be appropriate here to give a statement of the geologic history of limestone in Florida similar to that made for the siliceous deposits. The following is a list of the calcareous formations of the State, presented in stratigraphic sequence:

Pleistocene: Palm Beach limestone, Miami oolite, Key Largo limestone, Key West oolite, Lostmans River limestone.
Pliocene: Marls are abundant but limestone is not known.
Miocene: Jacksonville formation: Contains some limestone beds.
Oligocene:
    Apalachicola group: Alum Bluff formation, some impure limestone; Chattahoochee formation, mostly impure limestone; Hawthorne formation, some limestone; Tampa formation, some limestone.
    Vicksburg group: This group is composed mostly of more or less pure limestone. There are some marl and sandy beds and layers of chert.

In reviewing the geologic formation of Florida it is immediately evident that the Vicksburg group comprises the great limestone formations of the State. Although there are calcareous constituents in the Upper Oligocene, Miocene, and Pliocene, very rarely is there pure limestone; more frequently the material is composed of clays or sands with a large proportion of calcareous matter. In other words, Florida is very largely made up of continental waste, but the older geologic formations contain sufficient lime to furnish calcareous material to the streams flowing across their surface.

TERTIARY CORAL REEFS OF THE SOUTHERN UNITED STATES.

The rôle coral reefs have played in building up the Peninsula of Florida can easily be understood by outlining the geologic history of the reefs of that and adjacent regions as we now know them.

Oligocene, Vicksburg Group.—There was no extensive development of coral reefs during Vicksburgian time. In fact, the only reef known which may be referable to it is the one at Salt Mountain, near Jackson, Alabama. It is of comparatively few acres in extent, and regarded as a constructive geologic factor is of almost negligible importance.

Oligocene, Apalachicola Group.—Coral reefs belonging to this group are known at several localities. Probably the most extensive development is in the vicinity of Bainbridge, Georgia, where exposures may be seen along Flint River from a point 3 or 4 miles below that town through a distance of 4 or 5 miles. Reef corals of the same geologic age are also known from the McIntyre plantation, 11 miles south of Thomasville, and at other places in Thomas County, Georgia; and from southern Lowndes County. In Georgia, however, although there were Upper Oligocene coral reefs they were not of great importance as constructional agents.

In Florida, Upper Oligocene reef corals are known from several localities. The most northern is in Wakulla County, near Wakulla Station, between Tallahassee and St. Marks; fossil corals are also found at White Springs, on the Suwanee River; large heads of *Siderastrea* are abundant in the vicinity of Alachua, Alachua County, and the chalcedonic replacements of corals from the vicinity of Tampa are widely known. Compared to the total extent of the Upper Oligocene formations in Georgia and Florida, corals play an insignificant role; they possess more importance as furnishing means of correlating geologic formations than as constructional agents.

Miocene.—No coral reefs of Miocene age are known in the Atlantic and Gulf Coastal Plain. A few fossil species are known and for stratigraphic purposes they are of value.

Pliocene.—No Pliocene coral reefs are known. Professor Heilprin, in his discussion of the exposures along the Caloosahatchee River, called attention to the comparative scarcity of corals and the great abundance of shells in the Caloosahatchee marl. On Shell Creek corals are relatively more abundant, but they are not strictly reef-building species, belonging rather to species that grow on flats, and especially the inner flats behind keys.

Pleistocene.—The second extensive development of coral reefs in Florida took place in Pleistocene time.

Attention may be called to Captain Hunt's estimate of the time necessary for the formation of southern Florida. He bases his estimate on two assumptions: first, the rate of growth of corals as observed by him in the neighborhood of Key West; second, that the whole of southern Florida has been built up by the activity of these organisms, whose calcareous remains after having been pounded into sand by the sea go to form great limestone flats. Captain Hunt's estimate of the rate of growth of corals is open to doubt, and his second assumption is fundamentally wrong.

TRANSPORTING AGENTS OF THE FLORIDA COAST AND THEIR EFFECTS.

In the preceding pages an attempt has been made to give an account of the character of the sediments accumulating along the shores of southern Florida, to determine the sources of their constituents, to indicate the processes by which they were brought to the sea, and to trace in outline the stratigraphic distribution of similar material in the State. It is now proposed to consider the destiny of the sediment delivered to the ocean. This subject will be introduced by an account of the forces operating in the ocean to distribute the sediments or accumulate them in certain areas.

Currents are the agency by which distribution is effected, and are represented by three types, viz: (1) more or less constant oceanic currents; (2) tidal currents; (3) currents due to winds.

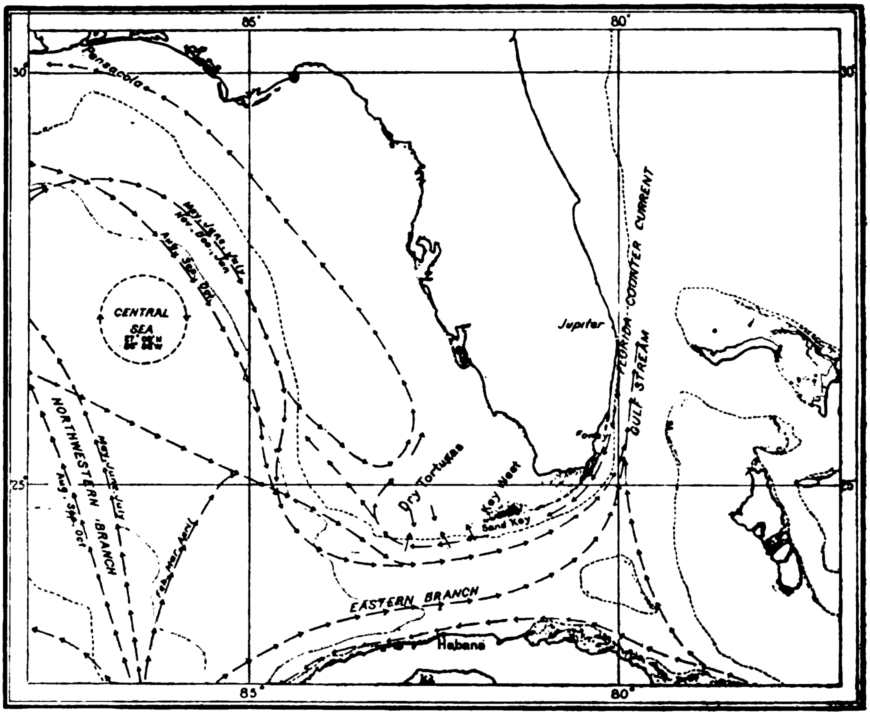

FIG. 3.—Current Chart of Florida Water (from Pilot Chart, Hydrographic Office, U. S. N.).

CONSTANT CURRENTS.

The most important constant current is the Gulf Stream, which flows along the 100-fathom curve, passing between the Florida Keys and Cuba on the south, and the eastern coast of Florida and the Bahamas on the east. This current can not directly have much influence on the sedimentation on the Floridian Plateau, although it is indirectly of great importance. The current of greatest direct importance is the countercurrent which follows the eastern coast of the United States from Cape Hatteras southward. In the Floridian region it is called the Florida countercurrent and has long been known to be an important factor in building up the Floridian Plateau, as is attested by the writings of Captain Hunt and Mr. Alexander Agassiz; and Dr. Gulliver has recognized its importance in determining the configuration of the shore-line. This current passes through the Straits of Florida and continues as far west as the Tortugas. The direction of its movement is southward until the southern extremity of the Peninsula is reached, where it turns westward.

According to the Pilot Chart of North Atlantic Ocean, March, 1909:

> In the Straits of Florida the countercurrent is very uncertain. Under favorable conditions of weather it extends as much as 11 miles offshore, but it generally makes a westerly course to Sand Key within the line of the reefs, though with certain winds it runs north or south between the keys and northeast around the Tortugas.

TIDAL CURRENTS.

The flow of the tides is transverse to the keys, and rather strong tidal currents pass in and out between the keys. These are strong enough to sweep the bottoms of the passages clean.

WINDS.

The following data on the winds of southern Florida are taken from the Pilot Charts of the North Atlantic Ocean for the year 1907, published by the Hydrographic Office of the Navy Department. No attempt will be made to present the data in detail, and only the prevailing directions of the winds for each month will be given:

Jan.: Northeast, east, northwest, north, southeast. (The component direction is from the northeast.)
Feb.: Southeast, northwest, east, and northeast.
Mar.: Southeast, northwest, northeast.
Apr.: Southeast, east, northeast.
May: Southeast, east, northeast.
June: Southeast, east, south.
July: Southeast, east, south.
Aug.: Southeast, east, south.
Sept.: Northeast, southeast, east.
Oct.: Northeast, east, north.
Nov.: Northeast, north, northwest.
Dec.: Southeast, northeast, east, northwest.

The preceding data show the prevailing direction of the winds to be from the southeast from February to August inclusive, varying from northeast to southeast from February to May, and from southeast to south from June to August; from the northeast from September to January, but with considerable variation. The general direction of the winds is either along or transverse to the line of the keys.

The tides and winds, as Captain Hunt suggested, tend to carry material from the reefs and flats to the area behind the keys; while the countercurrent moves material southward and westward. The winds and tides by agitating the sea-bottom bring material within the influence of the countercurrent and thus aid in its work of southward transportation. Without this assistance probably the countercurrent would not produce great effects.

EFFECT OF THE FLORIDA COUNTERCURRENT ON THE SHORE TOPOGRAPHY OF FLORIDA.

When a map of the east coast is examined, its long sweep and gentle curves are immediately observed; there are no prominent salients or deep indentations, no small irregularities, and for miles the shore-line may be almost straight. Several other features are to be correlated with the alongshore current.

(1) *Elongated sounds* called rivers paralleling and lying near the coast: north of St. Augustine are Tolomato or North River and Guano River, both of which empty to the southward, and south of that city is the Matanzas River which empties to the northward, the three finding an exit to the ocean through St. Augustine Inlet (fig. 5). The Matanzas River has a smaller inlet from the sea at its southern end. Following the coast southward, Halifax and Hillsboro rivers are in communication with the ocean through Mosquito Inlet. The latter "river" connects at its southern end with Mosquito Lagoon, which is just north of Cape Canaveral. Back of this cape and of the beach to the south of it is Banana River, which is barely separated from the northern portion of Indian River. In fact, Mosquito Lagoon, Banana River, and Indian River are all more or less in communication through Banana Creek, which forms an irregular, sinuous northern boundary of Merritt Island. Indian River is succeeded to the southward by Hobe and Jupiter sounds and Lake Worth. Between Hillsboro Inlet and the northern end of Biscayne Bay are several small lagoons and salt-water creeks.

(2) *The beaches and islands* along shore have their southern ends elongated, often pointed, while their northern ends are wider and frequently more or less truncated. Amelia Island, on which Fernandina is situated (fig. 4), is an instance of such an island with a truncated northern end. Anastasia Island, on the south side of St. Augustine Inlet, is another instance, but its northern end is not so obtuse as that of Amelia Island (fig. 5).

(3) *Southward Deflection of Stream-mouths.*—Two good instances of this phenomenon are seen in the vicinity of Fernandina (fig. 4). To the north of Anastasia Island is Cumberland Sound, through which St. Mary's River empties into the ocean; to the south is Nassau Sound, through which Nassau River flows. Both of these sounds are directed from the northwest to the southeast. New and Middle rivers, the streams next north of the upper end of Biscayne Bay, have their mouths deflected southward. The phenomenon is general along the Florida east coast.

(4) *Overlaps and Offsets.*[1]—Instances of both these phenomena are present and can be seen in the vicinity of St. Augustine (fig. 5). The point of land north of St. Augustine Inlet overlaps the northern end of Anastasia Island; overlap and offset are necessary accompaniments of the kind of stream deflection exhibited along this coast.

(5) *Current Cuspate Forelands.*—Gulliver has cited Cape Canaveral as an almost typical example of this shore form (fig. 6).[2]

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[1] Gulliver, Shore-line Topography, Proc. Amer. Acad., vol. XXXIV, 1899, p. 178.
[2] Proc. Amer. Acad., vol. XXXIV, p. 180, fig. 10.

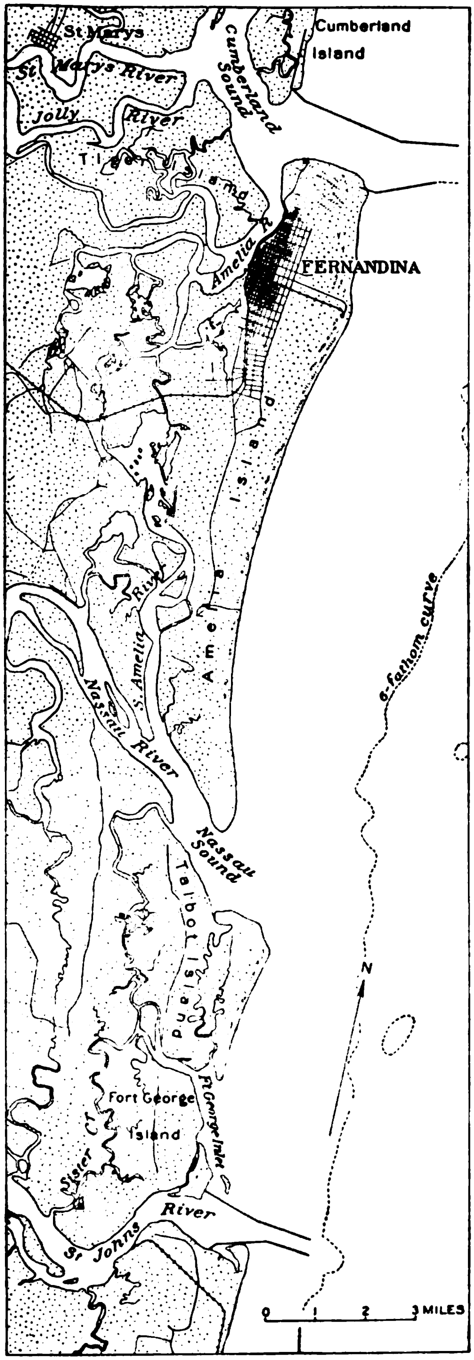

Fig. 4.—Map of the Florida Coast, from the mouth of St. Mary's River to the mouth of St. John's River. (From U. S. Coast Surv. Chart, No. 158.)

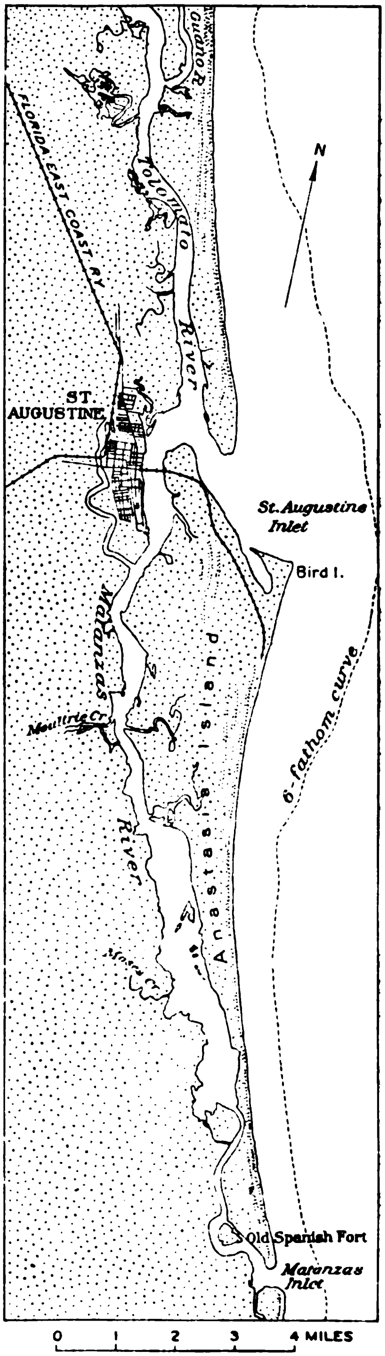

Fig. 5.—Map of Florida Coast in vicinity of St. Augustine. (From U. S. Coast Surv. Chart, No. 159.)

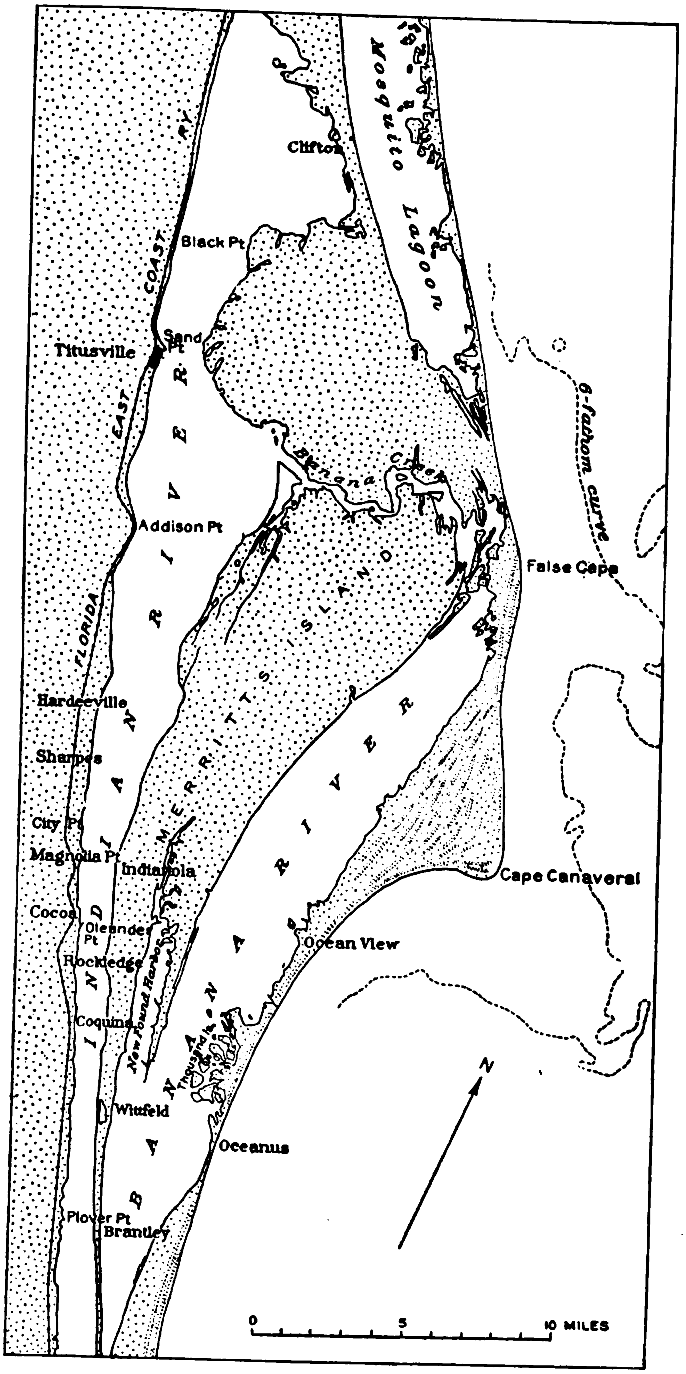

FIG. 6.—Map of Cape Canaveral. (From U. S. Coast Surv. Chart, No. 161.)

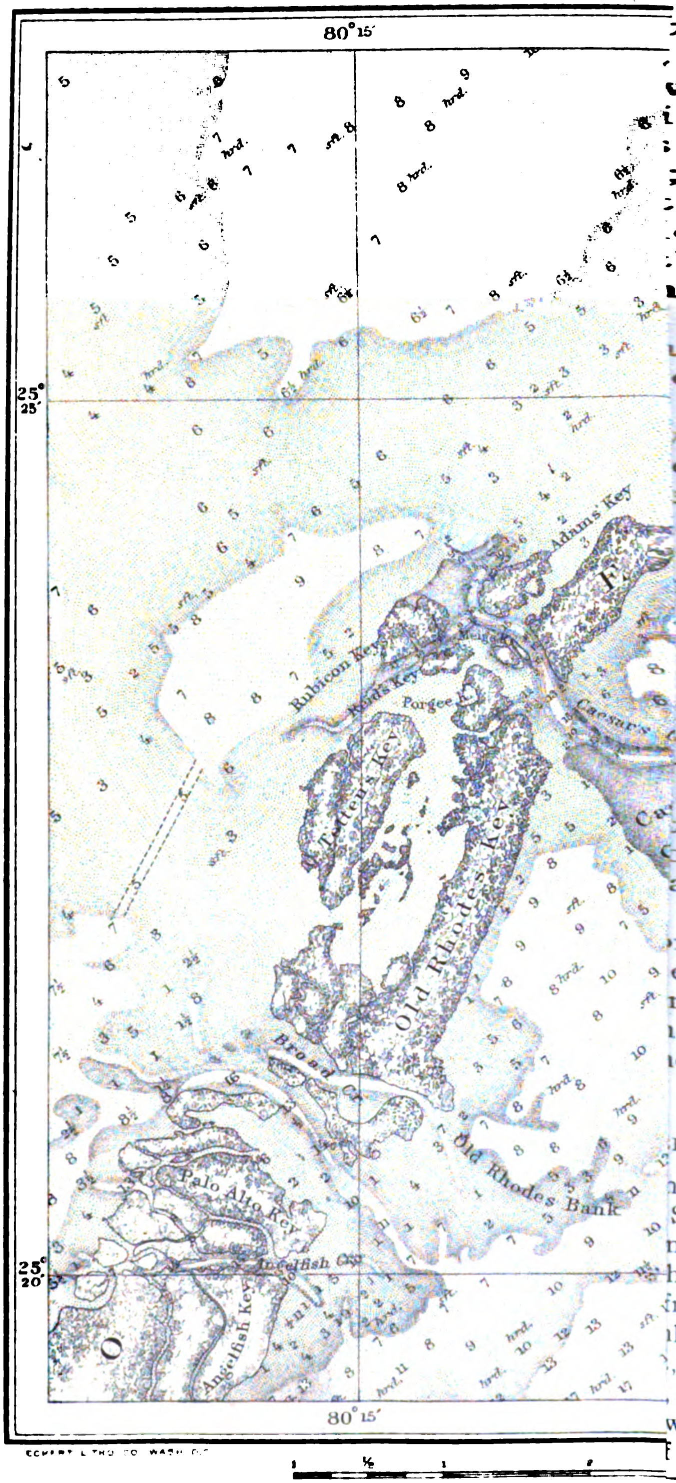

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PLATE 3

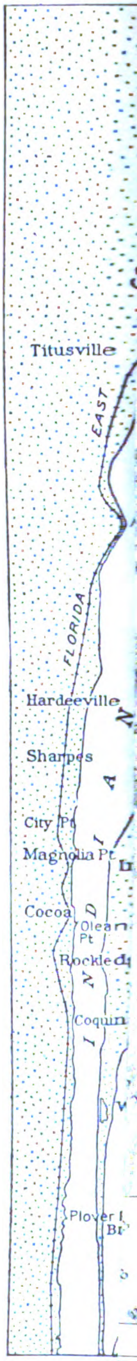
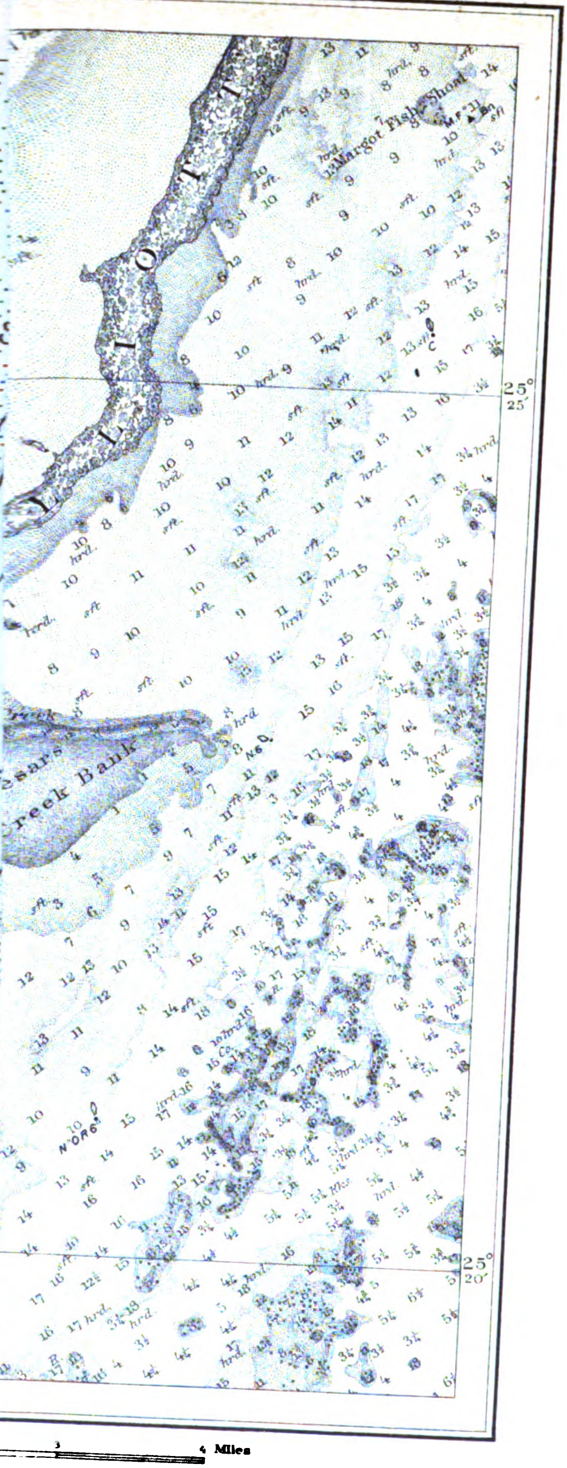


FIG. 6.



ND OLD RHODES BANKS

rvey Chart No. 166)

The west coast of Florida strongly contrasts with the eastern; the absence of prevalent alongshore currents is especially striking. Cape Sable seems current-shaped by alongshore currents. From Cape Sable to Cape Romano the coast line is minutely laciniate; from Cape Romano to Anclote Keys there is evidence of shore currents, keys with sounds behind them paralleling the coast; from Anclote Keys to the mouth of Ocklockonee River, just east of St. George Island, the coast is minutely irregular. From the eastern end of St. George Island the coast is swept by the countercurrent on the north side of the Gulf.

The preceding account of the shore-line topography of Florida from the standpoint of currents has an immediate bearing on contemporaneous sedimentation and the building of such sand-spits as occur on the eastern side of Biscayne Bay, and such keys as Virginia Key and Key Biscayne. Arenaceous material is swept southward by the ocean currents on the outside of this spit and the two mentioned keys; while behind them Snake Creek and Miami River are bringing their burdens of sand from the mainland. The tendency of the process is to fill up Biscayne Bay and not only to connect the spit and arenaceous keys to the mainland, but to join them to the coral reef keys farther south.

BANKS BEHIND KEYS.

Sediment, mostly calcareous, is accumulating in the bays and sounds behind the keys and is gradually filling them, although some is carried to the outside. As has been stated, the tides run across the line of keys, and the tidal currents have usually swept clean the channels between them; but behind them are regions of slack water, and shoals are built. The ridges and shoals behind Key Largo, Long Island, and the Metacumbes are very instructive. No hard material at all was found at any locality examined.

Mangroves are an important factor in this work of construction. When a shoal attains to about a foot of the surface of the water, the floating pods of these plants catch on the soft bottom, take root, grow, and develop root tangles below and tangles of branches above. They catch and retain floating débris and convert the shoal into an island. (See plates 9, 10, 11, and 12, fig. *a*.)

DELTAS AT OUTER ENDS OF PASSAGES BETWEEN KEYS.

Attention should also be called to the deltas forming at the seaward end of some of the passages between keys. Professor Shaler was the first to remark on this phenomenon,[1] stating, "The volume of the material can best be judged by the conditions exhibited by the deposits of limy matter at the eastward end of the channel passing from Biscayne Bay to the sea, known as Cæsars Creek." This is not the only locality at which such a delta is forming. The U. S. Coast Survey chart, No. 166, indicates one at the eastern end of Bear Cut, off Cape Florida, and at the mouth of Broad Creek, the last-mentioned bank being known as Old Rhodes Bank (plate 3). There are probably other instances of this phenomenon.

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[1] Topography of Florida, Mus. Comp. Zool., Bull., vol. XVI, p. 147, 1890.

AREAL DISTRIBUTION OF THE GEOLOGIC FORMATIONS.

This subject may be introduced by reference to the Table of Geologic Formations given on page 126 of this paper and to plate 4. For stratigraphic descriptions the "Preliminary Report on the Geology of Florida" by Messrs. Matson, Clapp, and Sanford[1] may be consulted.

OLIGOCENE.

VICKSBURG GROUP.

The rocks belonging to this group, the oldest geologic formation known on the Peninsula, form the surface of the area from Sutherland in the northwest corner of Hillsboro County northward to the vicinity of Newberry and Gainesville. The western boundary is almost on the water front at Sutherland and lies only 5 or 6 miles from the shore of the Gulf from that place to Crystal River, beyond which it curves to the northwest, roughly paralleling the shore at a distance of 6 to 12 miles from it, to 6 miles south of the latitude of Cross City. This boundary is slightly concave toward the west and is separated from the shore of the Gulf by a narrow fringe of Quaternary deposits, ranging from 1 to 12 miles in width. The northern boundary of the area is a slightly sinuous line running in an easterly direction from opposite Pine Point through Old Town, Newberry, just south of Gainesville, to Lockloosa. From the last-mentioned town, the boundary bends southward and passes through Sumterville, whence it extends southwestward to Sutherland. The eastern boundary is strongly convex to the east. North of this main area there are outlying small areas almost as far north as the latitude of Lake City. If the boundaries of the main area were extended so as to include the outliers, they would still retain a concavity on the west and a convexity on the east.

APALACHICOLA GROUP.

As is implied in the preceding paragraph rocks of the Apalachicola Group are not present between the western boundary of those of the Vicksburg and the Gulf. The rocks of the main Vicksburg area pass beneath the Apalachicola rocks on all sides except on the west, and all outlying areas of the former are surrounded by rocks of the latter group. The Apalachicola rocks continue northward into Georgia where outcrops of the Vicksburg limit their northern extension. They extend to the westward, separated from the coast by a margin of Pleistocene deposits, to the vicinity of the mouth of St. Marks River, where they reach the coast through a stretch of several miles. Thence they extend westward to the Ocklockonee River near Sopchoppy, from which place the boundary bends northward, passing west of Tallahassee; there it is sharply flexed to the west and crosses the Apalachicola River at Alum Bluff. Westward of a point 9 to 10 miles west of Tallahassee an area of Miocene (the Choctawhatchee formation) intervenes between the Apalachicola and the coastal fringe of Pleistocene deposits.

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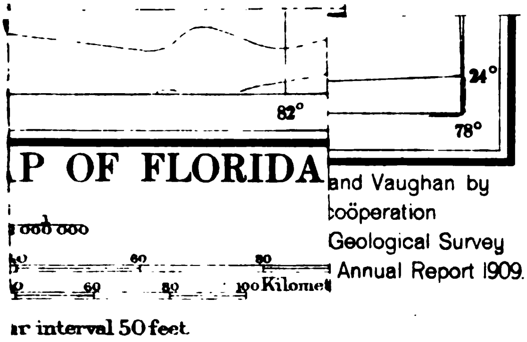
[1] Florida Geol. Surv., 2d Ann. Report.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Toward the east the Apalachicola Group is overlain near the eastern boundaries of Baker and Bradford counties by Miocene sediments (Jacksonville formation). The Miocene projects southward, as a tongue, over the Apalachicola as far as Waldo. Northwest from Palatka to the south fork of Black Creek the Apalachicola boundary is formed by the Pleistocene of St. John's River valley. Along the west side of St. John's River valley, from Palatka southward to Enterprise Junction, the boundary is formed by the overlapping of the Pliocene Nashua marl. The boundary curves to the southwest of the latter town, passes through Orlando, Lakeland, and reaches the Gulf at Tampa. Along this stretch from Enterprise Junction to Tampa, the boundary is between the Apalachicola and the Pleistocene. South of Tampa two small outlying areas of Apalachicola sediments are known, one at Ellenton near the mouth of Manatee River; the other at White Beach,[1] between Osprey and Sarasota.

MIOCENE.

Two Miocene areas are known in the State, a western and an eastern. The former extends westward from near Tallahassee, and is bounded on the north by deposits of the Apalachicola Group, and on the south by those of Pleistocene age. The eastern area has its western boundary formed by the Apalachicola Group. Except below the south loop of St. Mary's River, where the Apalachicola outcrops, the northern boundary is formed by Pleistocene deposits to St. John's River, about 6 miles north of Jacksonville. From Jacksonville to St. Augustine on the east the Miocene passes below Pleistocene and also from St. Augustine westward to the South Fork of Black Creek. This area of Miocene is bounded on the west by rocks of the Apalachicola Group; on the north, east, and south by Pleistocene.

PLIOCENE.

There are two principal areas of Marine Pliocene. The more eastern and northern of them (the Nashua marl) flanks the Apalachicola Group from Palatka to Enterprise Junction along the west side of St. John's River, and is overlain on the east by Pleistocene formations. On the northeast the boundary runs southeast from Palatka toward Daytona, thence it turns south to Osteen, then westward to Enterprise Junction.

The other area of Pliocene (the Caloosahatchee marl) is mostly overlain by Pleistocene deposits, and outcrops of it are seen only along streams, the Miakki River, Chiloccohatchee River, Peace, Prairie, and Alligator creeks, all of which flow into Charlotte Harbor and Caloosahatchee River.

PLEISTOCENE.

Southeast of the surface exposures of the Nashua marl and coastward of the southeastern and southern margin of the Apalachicola Group lying west of those exposures the entire surface to the sea front is formed by Pleistocene formations, except a few outliers of the Apalachicola Group, the marine Pliocene Caloosahatchee marls along some streams, and the non-marine Pliocene Bone Valley gravel near Bartow, from Homeland to Mulberry, and at Bone Valley.

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[1] It seems that this locality was not included by Messrs. Matson and Clapp in their report.

GENERAL RELATIONS OF GEOLOGIC BOUNDARIES IN FLORIDA.

The preceding account of the areal distribution of the geologic formation according to successive ages has been given to show how the rocks of Vicksburgian age form an eccentric nucleus, on whose northern, eastern, and southern slopes younger geologic formations have been laid down. The next younger group extended northward into Georgia, in which State the Vicksburg again comes to the surface; but toward the east, southeast, and south in Florida it is overlain by later sediments. The boundaries between older and younger sediments are roughly concentric to the Vicksburg nucleus on the east and south, tending to widen their areas to the south. This statement may appear doubtful, but when it is recalled that Apalachicola sediments extend from the northern end of Tampa Bay to below Sarasota Bay, a glance at the map will show the greater width along a north-and-south line in this area than along an east-and-west line through Palatka. A curved line would have to be drawn from Daytona to Lake Flirt on the Caloosahatchee to show the widening of the Marine Pliocene toward the south. South of St. Augustine the Miocene has been buried by Pliocene and later sediments.

The present coast line preserves this relation to the Vicksburg nucleus, but with the southward extension there has been a flattening opposite the eastern convexity of the old nucleus.

DRAINAGE LINES.

An examination of the map of Florida with reference to the drainage lines immediately shows that the State may be divided into two areas. In the extension westward from Aucilla River, a region actually a part of the main continental mass lying north of the Gulf of Mexico, the stream courses are normal to the Gulf Coast. The other area is the Peninsula portion of the State. In the latter there is a general conformity of the stream courses in the vicinity of the Vicksburg nucleus to its outline, while away from it they more or less parallel the east and west coasts.

The streams of the Peninsula are those of special importance for this discussion. Santa Fe River runs westward near the northern boundary of the Vicksburg, to its confluence with the Suwanee River, whence the latter stream trends southward across the northwestern corner of the Vicksburg area. Between the headwaters of the Santa Fe River and the Ocklawaha is a comparatively low divide with an elevation of very little over 100 feet. Ocklawaha River follows near the eastern boundary of the Vicksburg-Apalachicola from Lake Griffin northward to the latitude of Nashua; then it bends abruptly eastward and flows into St. John's River. Between the headwaters of the Ocklawaha and those of the Withlacoochee and Hillsboro rivers is a region of low relief, in which, excepting a few hills, no place attains an elevation of 100 feet above the sea. Hillsboro River approximately parallels the southeastern boundary of the Vicksburg-Apalcahicola groups. These data show that there is from the confluence of the Santa Fe with the Suwanee

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a valley approximately paralleling the northern, eastern, and southeastern boundary of the Vicksburg and the Apalachicola. (See plate 5.)

The only stream which does not conform to this arrangement is the Withlacoochee. A study of the map leads to the suggestion that it has been formed by a stream working backward from the coast across the Vicksburg area, and capturing a part of the headwaters of both Hillsboro and Ocklawaha rivers, so that the non-conformity of the Withlacoochee to the arrangement of the other streams is a later development.

The striking manner in which the northward flowing St. John's River parallels the coast has frequently been emphasized, but the trends of the southward flowing Kissimmee and Peace rivers are not less striking. South of the elevated region in the vicinity of Haines City, the two main drainage lines not only trend southward, but at their southern extremities are deflected toward the west. The deflection of Peace Creek is through Charlotte Harbor, and the Kissimmee flows through Lake Okeechobee, which is connected with the Gulf by the Caloosahatchee.

The trend of the drainage lines of Florida is therefore at first roughly concentric to the Vicksburg nucleus and proceeding away from this nucleus toward the east and the south the trends conform to the general scheme of arrangement of the geologic formations and to the coast line. The eastern coast of Florida follows a long sweep toward the southeast, then bends south and turns by a curve toward the west.

The analogies of the eastern and southeastern outlines of the Vicksburg nucleus, the arrangement of the main drainage lines, and the outline of the eastern and southern coasts of Florida are so striking that one is forced to the conclusion that some common cause lies beneath all of these phenomena.

GEOLOGIC HISTORY OF THE FLORIDIAN PLATEAU.

EVENTS OF VICKSBURGIAN TIME.

THE VICKSBURGIAN SUBMERGENCE.

During Vicksburgian time remarkable uniformity of marine conditions prevailed throughout an extensive area of what are now the southern United States, from central Louisiana, across Mississippi, Alabama, and Georgia, and similar sedimentation was also taking place on the Floridian Plateau, practically to its southern extremity, should the material from the deep well at Key West, studied by Hovey, be trustworthy. A well record from Palm Beach, given on page 127, shows that Vicksburg rocks were there encountered between 915 to 1,000 feet below the surface. At Key West, according to Hovey,[1] *Orbitoides* first appears in abundance at a depth of 900 feet.

DEPTH AND TEMPERATURE OF THE WATERS.

It is important to determine the approximate depth of the Vicksburgian Sea; as it is the oldest geologic formation known on the Floridian Plateau, light will be thrown on the age of the Plateau. The formation of an opinion on this subject may be made possible by data from two sources: (1) the material composing the sediments; (2) the character of the fauna.

In Florida, the Vicksburg Group has been tentatively divided into three formations, as follows: in west Florida, the Marianna limestone; on the Peninsula, "Peninsular" and Ocala limestones. Recent investigations in Georgia render it probable that only one formation should be recognized, for in that State the Ocala can be definitely identified, and no demarcation of the Marianna or "Peninsular" at present seems possible. In this discussion, which is an account of physical events, the "Peninsular" and Ocala limestones are spoken of collectively by the group-name Vicksburg. The Vicksburg limestones are predominatingly calcareous, as the terminology suggests, but they are not pure, considerable proportions of both clay and silica being present. Matson makes the following statement:

> These beds are uniformly fine-grained and show little variation in chemical composition. There is a predominance of limestone, though sand and clay occur in small quantities, and the percentage of these impurities in the limestone increases in the upper beds of this age. There is also an increased percentage of terrigenous material toward the northern end of the State, where the proximity of older land afforded opportunity for the entrance of considerable sand and mud into the Vicksburg sea. Toward the close of this period of deposition there appears to have been a shoaling of the seas which permitted the entrance of the fresh-water shells and the land-derived sediments noticeable in the Ocala limestone of the Vicksburg Group. The excellent state of preservation of many of these shells shows that the

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[1] Mus. Comp. Zool., Bull., vol. XXVIII, p. 67, 1896.

water must have been comparatively quiet during the deposition of the limestone. The inclusion of a small percentage of land-derived sediments and in some places of fresh-water shells shows that a portion of the limestones of Vicksburg age were probably deposited at no great distance from land. Locally the calcareous sediments appear to have contained large quantities of silica, probably in the form of tests of microscopic plants (diatoms) and spicules of sponges. (Florida Geol. Surv., 2d Ann. Report, p. 162, 1910.)

The most persistently conspicuous fossils of this group of rocks are foraminifera. Specimens and species of the genus *Orbitoides* are the most abundant. This genus occurs not only from bottom to top, but extends upward from the Jackson [1] below, and into the higher Chattahoochee.[2]

In the Jackson at Montgomery, Louisiana, *Orbitoides* is associated with shallow-water corals, as *Astrangia*; in the Vicksburg at Rosefield, Louisiana, and in Mississippi and Alabama it is associated with shallow-water mollusks, as *Ostrea.* The Vicksburg corals of Mississippi indicate a depth of water not over 50 fathoms, and it may have been much shallower. As the same species found in Louisiana, Alabama, and Mississippi occur in Georgia, a similar moderate depth is inferred for that region. The fauna of the area extending from Louisiana to the Savannah River distinctly indicates shallow-water conditions, probably a maximum depth of 50 fathoms, as the faunal associations of *Orbitoides* are those of shallow water, or less than 100 fathoms. Doctor Dall has given a list of species from the Ocala limestone in his Tertiary Fauna of Florida.[3]

The recent collections made by the Bureau of Fisheries steamer *Albatross* in the Philippine Islands throw additional light on this problem. At Station D 5179, off the northeast shore of Tablas Island (depth 37 fathoms, bottom temperature 76.2° F., bottom hard, sandy), hosts of foraminifera were obtained, two of which were identified by Dr. J. A. Cushman as *Operculina complanata* var. *granulosa* and *Amphistegina lessoni*. The material is remarkably similar to that of which the Vicksburg limestones are composed; and the two are faunally so similar that it seems a sound opinion to consider the conditions of depth and temperature for the two deposits as similar.[4] *Operculina complanata* var. *granulosa* is a common fossil in the Vicksburgian rocks in southern Georgia.

Mr. A. H. Clark informs me that he found large numbers of an *Orbitolites*-like form in shell sand brought up on the flukes of an anchor on the Grenadine bank near Union Island in a depth of between 4 and 7 fathoms.

The data presented in the foregoing remarks and the conclusion as to the depth of the Vicksburg Sea mean that the Floridian Plateau existed in Vicksburg time, and that its southern extent was about as great as it is at present. The date of the origin of the Plateau is therefore pre-Oligocene.

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[1] *Orbitoides dispansa* (Sow.) and *O. papyracea* (Boubée) are found in the Jackson at Montgomery, Louisiana.

[2] *Orbitoides* occurs in the basal Chattahoochee in the vicinity of Bainbridge, Georgia. *O. dispansa* (Sowerby) is the usual species.

[3] Wagner Free Institute, Transactions, vol. III, part VI, 1903.

[4] I am indebted to Dr. Paul Bartsch for the opportunity of using this note.

SUMMARY OF VICKSBURGIAN EVENTS.

The following statement of the early history of this Plateau seems substantiated:

(1) The Plateau was in time of pre-Oligocene origin.
(2) In Vicksburgian time there was an extensive submarine plateau reaching from Central Louisiana to the Atlantic Ocean, with a salient projecting from its southeastern corner as far south as the southern limits of the present land surface of Florida.
(3) The depth of water on this Plateau probably in no place was so great as 100 fathoms, more likely not over 50 fathoms.
(4) The temperature of the bottom was tropical or subtropical, between 70° and 80° F.
(5) Over the Plateau currents from the equatorial regions gently swept, with the general direction of the ocean drift probably from west to east. As no Vicksburgian strata have been found in Texas and as there is a great thickness of Eocene sediments in that State, it seems probable that there were extensive landmasses west of the Vicksburg Sea as well as north of it, and that these landmasses deflected the currents from the south toward the east. However, the data are not at hand for positively determining whether the main drift toward the east passed over the submarine plateau, or whether there was a countercurrent of warm water moving westward.
(6) Deposits of both terrigenous and organic origin accumulated on this Plateau to a depth ranging from 100 to 200 feet near shore to over 1,000 feet near the southern margin. As the maximum depth at which any of the deposits were formed was probably less than 100 fathoms, the deposition took place on a sinking sea-bottom. The depression, however, kept pace with the deposition of organic and detrital débris, thus permitting a considerable thickness of similar material to accumulate on the sea-floor.
(7) During the latter part of Vicksburgian time the sea-bottom was gradually elevated and a large area was uplifted into dry land.

THE VICKSBURGIAN-APALACHICOLAN INTERVAL.

A large area of the Vicksburgian sea-bottom was elevated above the sea-level before the initiation of the Apalachicola deposition; and this elevation extended as far south as Tampa, and perhaps further. The Apalachicola Group is divided into four geological formations, three of which, the Hawthorne, Chattahoochee, and Tampa, were in part at least contemporaneous; the fourth, the Alum Bluff, is geologically younger than the three others. The Chattahoochee formation lies in Florida to the northwest and north of the Vicksburg nucleus, and covers an extensive area in southern Georgia; the Hawthorne formation occurs in Central Florida to the north, northeast, and east of the Vicksburg; and the

Tampa lies to the south. The stratigraphic relations of each of these three formations to the Vicksburg have been studied by a number of geologists, and they have been found to rest in the eroded surface of the Vicksburg. Matson and Clapp have described these relations in detail in their Preliminary Report on the Geology of Florida.[1]

The uplift of the Plateau produced differential movement, and it is desirable to ascertain the relative amounts of movement in different directions, but at present sufficient data bearing on the problem are not available.

EVENTS OF APALACHICOLAN TIME.

The events of Apalachicolan time need separation into an earlier stage, represented by the deposition of the Chattahoochee, Hawthorne, and Tampa formations; and a later, represented by the Alum Bluff formation.

EARLIER STAGE.

SHORE-LINE.

The elevation which is described in the preceding section was followed by subsidence, and large areas that had been dry land were lowered beneath sea-level. The interior margin of the Apalachicolan Sea lay considerably to the north of the Florida-Georgia line in Georgia, and extended from the southwest corner of Decatur County northeastward to the boundaries of Burke and Screven counties on Savannah River. This sea was a shoreward portion of the Atlantic Ocean, but it seems probable that a small area in Florida, in northeastern Marion County, may not have been entirely submerged, and that in other areas over the Vicksburg nucleus these sediments were very thin. In Apalachicolan time a dome of Vicksburg rocks already existed. This land area in the Apalachicolan Sea, however, could not have been extensive, as rocks of Apalachicolan age occur as patches overlying the Vicksburg in Hernando County, the town of Brooksville being on one of them, and on the highland 6 miles west of Dade City, Pasco County, the Apalachicola forms the ridge from the altitude of 150 feet to the hill summit, 200 feet or somewhat higher. The Apalachicola therefore, it appears, entirely covered the summits of Hernando County and has been removed by erosion. Another outlying area of this group is at Levyville, Levy County. If the outlying patches are connected according to altitude with themselves and the main Apalachicola area, the only area remaining which was probably an island is the one near Orange Lake, on its southwest side, in Marion County.

MATERIAL OF THE SEDIMENTS.

The nature of the deposition in the Apalachicolan Sea varied greatly. Although calcareous constituents were common, argillaceous and arenaceous material frequently predominated. Matson and Clapp state. Florida Geological Survey, Second Annual Report:

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[1] Florida Geol. Surv., 2d Ann. Report, pp. 69, 75, 86.

> The changes from sediments of one character to those of another were frequently rapid, and during the entire time there was more or less intermingling of different kinds of sediments, giving rise to the marls, impure limestones, shales, and sands of this epoch.
>
> In the east and south central portions of the Peninsula the clay and sand predominated during the earlier part of this epoch, while farther north and west (also east on the Savannah River) similar deposits characterized the later stages. The calcareous materials which are found now in the form of marls and limestones were especially important in the area drained by the Apalachicola River, but they were also deposited in smaller quantities farther south and east. Throughout the period represented by the Apalachicola Group the conditions governing deposition appear to have differed considerably in neighboring localities, but there was no such abrupt variation as may be found along the present coast.

The facts recited in the preceding remarks indicate very shallow-water conditions.

FAUNAL CHARACTERS.

Some of the faunal characters of the older formations of this group are important. Coral reefs and massive corals which probably did not form reefs were present. They have already been alluded to in the section of this paper giving the stratigraphic distribution of reef corals, but may be repeated.

In Georgia fossil reef or massive corals have been reported from the following localities:

Decatur County: Flint River at Cherry Shoot, 3 miles below Bainbridge; Blue or Russell Spring, 4 miles below Bainbridge; Little Horse Shoe Bend, about 0.75 mile below the preceding locality; and Hales Landing, 7 miles below Bainbridge.
Grady County: 4 miles northeast of Forest Falls; 9 miles a little west of north of Whigham.
Thomas County: 3 miles west of Metcalf; 11 miles south of Thomasville; 3 miles west of Boston; 4.5 miles south of Boston.
Brooks County: 1.5 miles east of Quitman.
Lowndes County: Withlacoochee River, about 3 miles below the Valdosta Southern R. R. bridge; 2 miles northeast of Clyattsville.
Screven County: Old Jacksonboro near Bascom P. O.

In Florida the following localities are known:

Gadsden County: The vicinity of River Junction.
Wakulla County: The vicinity of Wakulla.
Suwanee County: White Springs on the Suwanee River.
Columbia County: 2 miles south of Lake City.
Alachua County: Numerous localities from 2 miles to 6 miles north of the town of Alachua.
Hillsboro County: Ballast Point.

These corals occur in each of the three local formations forming the lower portion of the Apalachicola group, viz: the Chattahoochee, the Hawthorne, and the Tampa.

SUMMARY OF EVENTS OF EARLIER STAGE.

From the nature of the sedimentation and the faunal characters the physical condition of the Floridian Plateau during this deposition period may be reconstructed with considerable accuracy.

(1) The Plateau had approximately the same outline as at present, reaching from the northern boundary of the Chattahoochee, which, as previously stated, extends from southwestern Decatur County to the boundary of Burke and Screven counties on the Savannah River, positively south of the latitude of Tampa, and probably to the northern edge of the Florida Strait. In the area now known as Marion County there may have been a small island of Vicksburg rocks.
(2) The depth of the water was probably at no place north of Tampa so great as 100 feet.
(3) The temperature was tropical, the lowest for the year at least as high as 70° F.
(4) As the temperature was tropical, the movement of the waters must have been from the tropics, by a direct or by a return or countercurrent.
(5) Terrigenous material was deposited over practically the whole submerged plateau surface.

LATER STAGE.

SHORE-LINE.

Conditions in the later stage of the Apalachicolan deposition had changed considerably from those of the earlier. The physiography of the region was different, and the approximate distribution of land and sea should be determined at the beginning of this section of the discussion. The sediments belonging to the Apalachicola Group subsequent in age to the Chattahoochee, Hawthorne, and Tampa formations are referred to the Alum Bluff formation. The northern boundary of the Alum Bluff extends from the higher summits in Decatur County northeastward to the Savannah River in southern Screven County. South of this line the sea extended beyond the base of the Florida Peninsula to an island with a north-and-south axis from Gainesville to Tampa, and an east-and-west axis from Ocala to the west coast. This island, here named Orange Island, may have extended farther westward and comprised territory now beneath the waters of the Gulf. A submarine platform extended southward of this island of Vicksburg and early Apalachicola sediments. The evidence of the deposition of later Apalachicola sediments southward of Orange Island rests upon the discovery by Matson and Clapp of fossils of the Alum Bluff horizon in the vicinity of Ellenton, on the Manatee River, south of Tampa[1]; and upon Dall's previous record of fossils at White Beach, Little Sarasota Bay, of an Oligocene horizon later than that of the Tampa localities.[2]

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[1] Florida Geol. Surv., 2d Ann. Report, p. 101, 1910.
[2] Wagner Free Inst. Sci., Trans., vol. III, pt. VI, pp. 1568–1570.

SUWANEE STRAIT AND ORANGE ISLAND.

Orange Island was separated from the mainland to the north by a broad strait, the Suwanee Strait of Dall.[1] That marine conditions prevailed across this area is proven by the occurrence of Alum Bluff species of fossils at White Springs on the Suwanee River, where Matson and Clapp obtained specimens of *Ostrea rugifera* Dall, *Pododesma scopelus* Dall, and *Pecten madisonius* var. *sayanus* Dall.[2]

For the details of the Alum Bluff formation across northern Florida the report of Matson and Clapp in the Second Annual Report of the Florida Geological Survey may be consulted.

DEFORMATION.

It is evident from the preceding remarks that during Apalachicolan time there was differential earth-movement in the Floridian region. As all of the sediments were laid down in shallow water, the sea-bottom must have been subsiding to receive the considerable thickness known to be present in west Florida and through the Suwanee Strait; while the area represented by Orange Island was a region of uplift. These changes in physiography were accompanied by changes in sedimentation, in climate, and in the fauna.

TEMPERATURE.

The basal bed of the Alum Bluff formation on the Apalachicola and the Chipola rivers is a yellow clay marl, the Chipola marl member, replete with excellently preserved fossils, indicating a tropical temperature. The yellow color is noteworthy, as it is predominant in the older stage of the Apalachicolan time. The climatic conditions have been the subject of detailed consideration by Dall.[3] During the latter part of Apalachicolan time the waters gradually cooled, ultimately becoming temperate. These changes are most appropriately described by Dall, whose account is here quoted:

> As indicated by the changes in the fauna, the physical changes attending the close of the Oligocene were at first slow, allowing a certain element of transition to appear in the Oak Grove or uppermost Oligocene fauna. At the last they appear to have been sudden, at least the change in the fauna on the Gulf coast was absolute and complete. The change was not only in the species and prevalent genera of the fauna, but a change from a subtropical to a cool temperate association of animals. Previously, since the beginning of the Eocene, on the Gulf coast the assemblage of genera in the successive faunas uniformly indicates a warm or subtropical temperature of water, and the sediments uniformly show, from the Jacksonian upward, a yellowish tinge due to oxidation. In the Oak Grove sands come the first indications of a change towards the gray of the Miocene marls. With the incursion of the colder water the change becomes complete. Not only do northern animals compose the fauna, but the southern ones are driven out, some of them surviving in the Antilles to return later. Some change along the northern coast permitted an inshore cold current to penetrate the Gulf, depositing on the floor of the shoal Suwanee Strait, separating the island of Florida from the continental shore, a thin series of Miocene sediments, which were also carried as far south as Lake Worth on the east coast of Florida and Tampa on the west coast, as shown by artesian borings. (*Op. cit.*, pp. 1549, 1550.)

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[1] U. S. Geol. Surv., Bull. 84, p. 111, 1892.

[2] Florida Geol. Surv., 2d Ann. Report, p. 100.

[3] Wagner Free Inst. Sci., Trans., vol. III, pt. II, pp. 1574–1575, 1903.

The series of Apalachicolan events was terminated by a general elevation of the Plateau.

ABSENCE OF APALACHICOLA SEDIMENTS WEST OF THE VICKSBURG NUCLEUS.

Before taking up the discussion of the subsequent stages in the history of the Plateau, the very striking peculiarity of the present surface distribution of the geologic formations will again be noticed. The Apalachicola Group is not now exposed above sea-level on the seaward side of the Vicksburg exposures in Lafayette, Levy, Citrus, and Hernando counties; nor does any later geologic formation except a coastal fringe of Pleistocene occur above sea-level in that area. As it does not seem at all probable that no Apalachicola sediments were laid down in this area, the explanation may be found in erosion during the Apalachicolan-Miocene uplift, or in a subsequent depression which submerged the Vicksburg-Apalachicola boundary. The growth of the Peninsular land-surface toward the east, southeast, and south, while there has been no addition of importance on the west since Oligocene time, will be considered on later pages.

APALACHICOLAN-MIOCENE INTERVAL.

The uplift closing Apalachicolan deposition carried areas of the former sea-bottom above the sea-level, and was followed by the subaerial erosion of the Apalachicola sediments. The evidence of the erosion of the Apalachicola previous to the deposition of the Miocene is seen at Alum Bluff on the Apalachicola River and at Jackson Bluff on the Ocklockonee River. At both localities the upper surface of the Alum Bluff formation shows distinct erosion furrows and channels, with the Miocene (Choctawhatchee formation) filling and overlying the irregularities.[1] It is difficult to find a gage of the amount of this elevation, but it is evident that extensive areas of the Apalachicola sediments became dry land and the subsequent Miocene depression did not again carry all of them below the ocean level.

On the east coast, in the vicinity of Jacksonville and St. Augustine, it appears from well-borings that sediments of Apalachicolan age are either very thin or even absent,[2] the Miocene apparently resting on the eroded surface of the Vicksburg. It is probable that the rocks of the Apalachicola Group were entirely or almost entirely eroded away over this area during the erosion interval immediately previous to the Miocene depression.

EVENTS OF MIOCENE TIME.

DISTRIBUTION OF MIOCENE SEDIMENTS.

The Miocene was another period of subsidence and the sea was again admitted over a considerable area of the Apalachicola sediments which had been subjected to subaerial denudation, but not all of the previous land area of those sediments returned to marine conditions. The present surface distribution of Miocene deposits is from a locality about 9 miles southwest of Tallahassee westward along the western extension of the State. This is a narrow strip, 6 to 12 miles wide, bounded on the north by the Apalachicola Group, on the south by Pleistocene deposits, except at the eastern end of the area where the Miocene has been eroded and the Apalachicola is exposed southwest of Wakulla River. No Miocene outcrops are known on the base of the Peninsula between Tallahassee and Trail Ridge, which forms the divide between the headwaters of Santa Fe River and the St. John's River drainage. Miocene sediments compose Trail Ridge whence they extend eastward to Jacksonville and St. Augustine. The Miocene Sea extended northward, Miocene fossiliferous deposits being known at Brunswick, Doctortown, on the Altamaha River, and at Porter's landing in Effingham County, on the Savannah River, in Georgia. South of the latitude of St. Augustine the Miocene is usually overlain by more recent deposits, and few exposures have been reported. The reported localities are given in the following notes:

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[1] Vaughan, in Matson and Clapp's report, Florida Geol. Surv., 2d Ann. Report, pp. 114, 115.

[2] Matson and Clapp, Florida Geol. Surv., 2d Ann. Report, p. 108, 1910.

Dall[1] reports *Pecten jeffersonius* and *Carditamera arata* from Preston sink, 3 miles north of Waldo, Alachua County, a locality at the southern end of Trail Ridge; and *Venus rileyi*, *V. permagna*, and *Arca limula* at a depth of 208 feet in a well at St. Augustine. The presence of *Pecten madisonius* in a collection of Pliocene fossils from the banks of St. John's River, a quarter of a mile below Nashua, Putnam County, indicates Miocene at that locality.[2] *Pecten* of the type of *madisonius*, and a *Chione* of the type of *cancellata* were obtained from a well at De Land, the former suggesting Miocene as the age of the bed.[2]

E. A. Smith obtained from Rock Springs near Zellwood, Orange County, *Pecten madisonius*, *Venus alveata*, *Venericardia granulata*, *Carditamera arata*, and *Mytiloconcha incurva* identified by Heilprin.[3] Heilprin reports from Rocky Bluff on the Manatee River, 5 or 6 miles above Braidentown, *Arca incongrua*, *Perna maxillata*, *Pecten jeffersonius*, *P. madisonius*, and *Venus alveata*.[4] Dall states that "it is probably from more westerly submarine strata belonging to this series of beds that was derived the *Ecphora* collected by Doctor Stearns in 1868–69 on the beach of Long Key."[5] Miocene fossils, *Pecten jeffersonius* and *Pecten madisonius*, were also obtained by Professor Heilprin on Phillips Creek, which flows into Little Sarasota Bay.[6]

No Miocene outcrops occur between the Vicksburg and Apalachicola areas of the Peninsula and the west coast.

Well-borings show that Miocene is present beneath later formations even as far south as the keys. The records of the Palm Beach well given on page 127 of this paper show Miocene between 800 and 915 feet and perhaps at 400 feet beneath the surface. The deep well at Marathon on Key Vaca (see page 128) revealed probably Miocene fossils between 375 and 420 feet below the surface. The arenaceous composition of the Miocene near the southern edge of the Plateau has already been stated, but may be repeated.

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[1] U. S. Geol. Surv., Bull. 84, pp. 124, 125, 1892.
[2] Matson and Clapp, Florida Geol. Surv., 2d Ann. Report, p. 122, 1910.
[3] Am. Jour. Sci., 3d ser., vol. XXI, p. 302, 1881.
[4] Wagner Free Inst. Science, Trans., vol. I, p. 13, 1887.
[5] U. S. Geol. Surv., Bull. 84, p. 125, 1892.
[6] Dall, *op. cit.*, p. 126.

LITHOLOGY.

Lithologically the Miocene of the western area (the Choctawhatchee formation) and that of the eastern (the Jacksonville formation) are decidedly different. The former is predominantly arenaceous, the sands are of a greenish color, weathering yellow or reddish, with an abundance of well-preserved fossil shells, overlain at Alum Bluff by a bed of plastic clay; the latter contains light-colored, impure, arenaceous limestone beds, particularly near the top, with a large amount of argillaceous material, varying in color from light gray to pale yellow.[1] There are sands and clays below the limestone beds of the Jacksonville formation. The thickness of the Choctawhatchee formation varies from 25 to 50 feet, while that of the Jacksonville may be from 400 to 500 feet.

MIOCENE CORALS.

Attention has not been called to the changes in the coral fauna of the Miocene from that of the preceding Apalachicola Group. The change in it is more striking, if not more important, than that in the mollusks. Reef corals abounded in the older beds of the Apalachicola Group. Corals of that type become rarer in the younger deposits of that group, and are entirely absent in the Miocene formations. The change is dramatic in its intensity.

SHORE-LINE.

In reconstructing the marine conditions of Miocene time the approximate shore-line must be determined, and the focal point of interest is the Suwanee Strait. As has been stated, no Miocene deposits are definitely known between Tallahassee and Trail Ridge. The altitude of the exposures near Tallahassee is about 100 feet; near Trail Ridge they attain a height, according to the map, of 200 feet. Intervening altitudes are above 150 feet, as at Lake City and Houston. Dall says:

> West of Jacksonville, at Live Oak, Suwanee County, and Lake City, Columbia County, specimens of fossils were obtained which may prove to belong rather to this (Jacksonville formation) than to the Chattahoochee group of beds. (U. S. Geol. Surv., Bull. 84, p. 125, 1892.)

This is a surmise and not an opinion, and later work has not verified the surmise, but it seems probable that Miocene deposits may have extended across this intermediate area. Matson and Clapp say:

> At the close of the Oligocene the State of Florida appears to have had the same general form that it now has, though its area was doubtless less than it is at the present time. With the inauguration of the Miocene there came a submergence which appears to have reduced the land area to a narrow strip along the northern end of the State, and a peninsula which was shorter and narrower than it is at present. During part of this period the central portion of the peninsula may have been separated from the mainland by a shallow strait. The exact extent of the encroachment of the sea during Miocene times is difficult to determine because

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[1] Matson and Clapp, *op. cit.*, p. 108.

> the deposits have been partially removed by subsequent erosion and their present extent is often obscured by considerable thickness of younger beds. (Florida Geol. Surv., 2d Ann. Report, pp. 165, 166, 1910.)

The question as to whether or no the Miocene sea extended through the Suwanee Strait must for the present remain without a definite answer. The available evidence now permits only the statement that the Strait may have again had ocean currents flowing through it. Except in the Suwanee Strait region, the Miocene shore may be outlined with considerable definiteness. In west Florida it reached from a short distance north of the present Apalachicola-Miocene boundary, probably not extending to the southern limits of Georgia, into Alabama in the vicinity of Mobile. The problematic condition of the Suwanee Strait has been fully discussed; it is not positively known whether the Strait was open, or whether there was a short peninsula bounded on the east by a shore-line just west of Trail Ridge and projecting as far south as Tampa. Doctor Dall has at my request contributed the following remarks to this discussion:

> In the absence of evidence which would conclusively prove the post-Oligocene existence of the Suwanee Strait, one consideration had much weight with me in assuming it as highly probable. This is connected with the presence of the phosphate beds in the central peninsular region of Florida. There is practically no doubt as to the origin of these beds from the presence in Miocene and perhaps later times of immense rookeries of birds, and perhaps other animals, whose guano was absorbed by the porous limestone underlying their chosen habitat. Now experience shows that such rookeries are invariably separated from possible incursions of carnivorous continental enemies by impassable bodies of water. Otherwise the birds could not maintain themselves, and the occupation of their rookeries for a period, such as was necessary for the formation of the phosphatic deposits, would have been impossible. The erosion of shallow beds of Miocene age under conditions which have existed in Florida, over part of the area of the supposed strait, is not an exceptional or remarkable phenomenon; and it is quite possible that more exhaustive exploration than has yet been possible may reveal traces of the missing Miocene sediments.

In Georgia the shore of the Miocene sea lay somewhat west of a line passing through Doctortown, on the Altamaha River, and Porter's Landing, on the Savannah River, but it did not entirely overlap the Apalachicola sediments. All of Florida excepting the land areas indicated was submerged.

DEPTH OF WATER.

The depth of the sea is shown by both the kind of sediments and the fauna. The sediments are near-shore, shallow-water deposits, and are predominantly terrigenous, although there is some lime in the Jacksonville formation, probably chemically precipitated, and lime of organic origin, the calcareous remains of fossils. The fossils, comprising such genera as *Ostrea*, etc., indicate shallow-water conditions. The Floridian Plateau extended to the southern margin of the keys, as shown by the deep well at Marathon, Key Vaca. Probably at no place over the platform did the depth exceed a few fathoms, 25 or 30 seems a safe maximum. The maximum thickness of the Choctawhatchee formation, 50 feet, demands no continuous depression of the sea-bottom along the western extension; but the thickness of the Jacksonville formation, 400 to 500 feet, indicates progressive subsidence during a portion of Miocene time.

TEMPERATURE.

Dall has given an excellent statement of the temperature of the Miocene waters of the region (see quotation on page 156). He also says:

> As I have on various occasions insisted, the faunal gap between the uppermost Oligocene (Oak Grove)[1] and the Chesapeake or Miocene is the most sudden, emphatic, and distinct in the whole post-Cretaceous history of our southeastern Tertiary, and indicates physical changes in the surrounding region, if not in Florida itself, sufficient to alter the course of ocean currents and wholly change the temperature of the waters of our southern coast. (Wagner Free Inst. Sci., Trans., vol. III, pt. VI, p. 1594, 1903.)

Temperature conditions had within a relatively short time passed from tropical to those of the latitude of Chesapeake Bay, or even the southern coast of Cape Cod and Long Island.

In an attempt to deduce the temperature of the Miocene waters of Florida, the data presented in Sir John Murray's "On the Temperature of the Floor of the Ocean and of the Surface Waters of the Ocean"[2] have been used. As the Miocene fauna was one of shallow water, the bottom temperature was probably not greatly different from that of the surface. It may also be said that the minimum temperature of the winter months is much more influential in determining the distribution of organisms than the maximum temperature of the summer months. For instance, according to Map 3 of the paper cited, a summer temperature of 80° to 90° F. extends from the Caribbean Sea and Gulf of Mexico northward to New York Harbor, or during the summer a tropical temperature extends far northward.

In the winter conditions are very different. The minimum temperature for the west coast of Florida is between 60° and 70° F.; for south Florida and the east coast, between 70° and 80° F.; on the south side of Cape Hatteras, 40° to 50° F.; north of Hatteras to Delaware Bay, 30° to 40° F.; north of the last-named locality the temperature may be below 30° F. Therefore during the Miocene the minimum winter temperature of the waters was at least as low as between 40° and 50° F. and it may have been as low as between 30° and 40° F.; or between 20° and 30° F. cooler than the present winter temperature of the west coast, and between 30° and 40° or even 50° cooler than the present winter temperature of the east coast.

CURRENTS.

There was indisputably, as Dall has so often emphasized, a cold current admitted along the shores of the land of embryonic Florida, assuredly as far west as Pensacola Bay. This current could not have been from the Equator, but must have been a southward flowing return or countercurrent from the north; and in my opinion this countercurrent initiated that series of countercurrents so important in the subsequent accumulation of sediments on the Floridian Plateau, and the formation of much of the present land surface of Florida. It brought sand and other terrigenous material from the north to be dropped on the Plateau, causing its surface gradually to approach sea-level. The transportation of sediment from the north by a current flowing down the western side of the Peninsula or island of Vicksburg and Apalachicola formations partly explains why the land surface has grown on the east and south and why there has been so little growth on the west. It partly explains the arrangement of the surface outcrop of the later geologic formations with reference to the older eccentric nucleus, and the arrangement of the main drainage lines, described on preceding pages. It also partly explains why there are 400 to 500 feet of Miocene sediments on the east coast and only 25 to 50 feet on the westward extension. The burden of sediment brought to the ocean by streams in Georgia and the Carolinas was by the agency of this current moved southward to the Florida bank. Henceforth, the development of Florida was largely dominated by the southward moving shore currents.

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[1] The Shoal River marl, member of the Alum Bluff formation, has been subsequently differentiated. (Vaughan, in Matson and Clapp, Preliminary Report on the Geology of Florida, Florida Geol. Surv., 2d Ann. Report, pp. 104–106, 1910.)

[2] The Geograph. Jour., July, 1899.

UPLIFT AT THE CLOSE OF THE MIOCENE.

Toward the close of Miocene time the Plateau was again subjected to an upward earth-movement, whereby the Suwanee Strait, which, should it have been open during a portion of the period, was definitely closed, and it is probable the Trail Ridge was uplifted. There was more upward movement on the east and south than on the west, for no Miocene was brought above the sea-level along the shore from Levy to Pasco counties, while submerged Miocene is apparently present off the mouth of Tampa Bay.

EVENTS OF PLIOCENE TIME.

STRATIGRAPHIC RELATIONS OF PLIOCENE TO MIOCENE SEDIMENTS.

There is a lack of definiteness of information regarding the stratigraphic relations of the Pliocene to the Miocene sediments. It is not positive whether there was a subsidence at the beginning of the Pliocene or whether Pliocene sedimentation took place on areas of the Miocene that remained submerged. Matson and Clapp say concerning the stratigraphic position of the Pliocene Nashua marl of St. John's River valley:

> The Nashua marl is thought to rest unconformably upon the Miocene at De Land, but this opinion lacks confirmation, as the collections from that locality have not been studied in sufficient detail to determine the exact age of the beds. (Florida Geol. Surv., 2d Ann. Report, p. 128, 1910.)

The same authors say concerning the Caloosahatchee marl:

> The contact of the Caloosahatchee marl with the underlying Miocene has not been observed, but there is considerable change in fauna between it and the Miocene, which is probably due to physiographic changes which may have permitted the erosion of the Miocene beds before the beginning of the Pliocene deposition.

AREAL DISTRIBUTION OF MARINE PLIOCENE IN FLORIDA.

There are two important areas of marine Pliocene in Florida. The more northerly, the Nashua marl, occurs along the St. John's River valley from the vicinity of the town of Nashua southward to Enterprise

Junction, and extends eastward until overlain by Pleistocene deposits. There are certain peculiarities of this formation that should be noticed. The following five species, collected at Nashua, *Eupleura miocenica* var. *intermedia* Dall, *Ilyanassa porcina* Say, *I. isogramma* Dall, *I. granifera* Conrad, and *Nassa scalaspira* Dall, occur in the Waccamaw Pliocene of the Carolinas, but not in the Caloosahatchee marl of Florida. The presence of *Pecten madisonius* suggests Miocene in the same bluff, and that both Miocene and Pliocene are represented, but the beds have not been differentiated.

Exposures of Pliocene marl occur at the following additional localities southward along the St. John's River: 0.5 mile above the Atlantic Coast Line bridge over St. John's River, Putnam County; 0.5 mile south of De Leon Springs Station, Volusia County, 5 miles below Sanford railroad bridge, east side of St. John's River, and perhaps 7 miles below Sanford railroad bridge.

Proceeding southward the species belonging to the Waccamaw fauna disappear; they are found only at Nashua; and the southern exposures seem geologically younger. In the exposure 7 miles below the Sanford railroad bridge, every species might be Pleistocene, and the exposure was tentatively referred to the Pleistocene because of its similarity to the one 5 miles below the bridge.

In the northern drainage ditch 6.5 miles west of Fort Lauderdale, Mr. Matson obtained 17 species of fossils that were specifically identified; 16 of these are also Recent, and one, *Strombus leidyi*, was not previously known from beds younger than the Caloosahatchee. This exposure was tentatively referred to the Pleistocene because of its relation to other exposures definitely Pleistocene. These facts lead to the inference that southward from Nashua younger Pliocene beds are encountered, and that the Pliocene fauna is very gradually supplanted by that of the Pleistocene.[1]

A considerable collection of Pliocene fossils was obtained from a well on the property of Mary Boss, on an island in Lake Tohopekaliga, about 3 miles from Kissimmee, at a depth of 150 feet. The Pliocene is here overlain by at least 100 feet of Pleistocene beds.

The eastern Pliocene area overlaps the Miocene, and flanks the eastern side of the Apalachicola Group, extending southward along St. John's River valley from Nashua to Sanford; it is overlain on the east and south by Pleistocene deposits, but is shown by well-borings to be present at a depth of 150 feet in Lake Tohopekaliga. No surface exposures of marine Pliocene are known between Sanford and Zolfo Springs on Peace Creek.

The Caloosahatchee marl constitutes the second, the more southerly, of the marine Pliocene formations. The type locality is along the Caloosahatchee River from Fort Thompson, near Labelle, to Olga. This river stretch has been studied and described by Heilprin,[2] Dall,[3] Matson and

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[1] A collection made by me on North Creek, near Osprey, Manatee County, furnishes additional evidence in favor of this opinion. Besides usual Pleistocene species I also obtained at this locality specimens of *Pyrazisinus scalatus* Heilprin, a species previously known only from Pliocene beds.

[2] Wagner Free Inst. Sci., Trans., vol. 1, pp. 22–33, 1887.

[3] U. S. Geol. Surv., Bull. 84, pp. 142–146, 1892, and Wagner Free Inst. Sci., vol. III, pt. VI, pp. 1603–1614, 1903.

Clapp,[1] and I went over it with the two last-named geologists. Thanks to the splendid researches of Dall, no Tertiary horizon is paleontologically better known.

Besides the exposures along Caloosahatchee River, others are known along streams or the tributaries of streams flowing into Charlotte Harbor, viz: Miakki River, Chiloccohatchee River, Peace Creek, as far north as Zolfo Springs, Prairie Creek, Alligator Creek, and the famous Shell Creek; and along streams that do not flow into Charlotte Harbor, "Rocky Creek, which flows into Lemon Bay, near Stump Pass." [2] Considerably east of Peace Creek beds of marl containing "large clams" have been reported to Mr. Willcox as occurring on the banks of Arbuckle Creek.[3]

The last-mentioned exposure deserves careful investigation, as it is directly in line between the Caloosahatchee exposures and the buried Pliocene of Lake Tohopekaliga.

It has not so far been possible to differentiate Pliocene from Pleistocene and Miocene in the well-borings south of the latitude of the southern end of the Lake Okeechobee, but it is not to be doubted that Pliocene is represented in the wells. The borings, however, do not indicate any great changes of deposition conditions.

LITHOLOGY AND THICKNESS.

Both the Nashua and Caloosahatchee marls bear close lithologic resemblance, both consisting of shell marls interstratified with beds of sand. The maximum thickness of the former is about 32 feet at De Land[3]; that of the latter probably about 25 feet.[4]

SHORE-LINE.

The Pliocene submergence was not so extensive as that of the Miocene. The shore-line lay west of St. John's River from Palatka southward to opposite Sanford, whence it continued southward keeping on the west side of Lake Tohopekaliga; it probably passed around the southern end of the ridge on which Haines City is situated, and then turned southwest to the vicinity of Sarasota Bay. Probably the territory east of St. John's River extending from Palatka northward to beyond Jacksonville, was also submerged. There is no evidence of any submergence of the west coast north of Tampa.

DEPTH AND TEMPERATURE OF THE PLIOCENE SEA.

Dall has attempted to reconstruct the conditions of depth and temperature prevalent during the deposition of the Caloosahatchee marl. He says:

> The assemblage of species on the whole, in the principal stratum, is such as one might expect to find in water from 20 to 25 feet in depth, judging by what we know of living mollusks. Mixed with these are a certain number of shallow-water forms which may be supposed to have flourished as the water became shoal by

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[1] Florida Geol. Surv., 2d Ann. Report, pp 123–128, 1910.

[2] Dall, U. S. Geol. Surv., Bull. 84, p. 148.

[3] Matson and Clapp, Florida Geol. Surv., 2d Ann. Rept., p. 129.

[4] Matson and Clapp, *op. cit.*, p. 124.

> elevation of the sea-bottom. There were lagoons of fresh water and probably streams emptying into the sea and in time of flood sweeping their fresh-water population out onto the shoals, where it perished. Part of the bottom became elevated nearly to the surface, oyster banks were formed on it, and the compacter parts became water-worn. The absence of shells like *Litorina* and *Nerita* seems to indicate that the dry beaches were muddy or sandy rather than rocky. In the course of time elevation so shoaled the water that only species like *Venus cancellata* and others able to live between tide marks could remain. This portion of the formation constitutes the so-called *Venus cancellata* bed, though neither of its component species is peculiar to it. Finally the area became cut off almost entirely from the sea and occupied more or less by fresh-water ponds in which the pond snails multiplied in myriads. (U. S. Geol. Surv., Bull. 84, pp. 145, 146.)

Concerning *Venus* (*Chione*) *cancellata*, Dall says in a preceding paragraph:

> In this connection it may be stated that *Chione cancellata* is known from the Chipola Old Miocene [Apalachicola Group] marls, in no respect differing from recent specimens, and that it has continued as a conspicuous member of the Florida fauna (except during the epoch when the Ecphora beds [Miocene] were being deposited) up to the present day. It is a warm-water shell and extended in abundance farther north during Chipola times and the newer Pliocene than during the period when the beds of the Chesapeake Group were being deposited or at present. The last-mentioned periods were and are entirely relatively cooler, and the two former relatively warmer, judging by the fauna. The species has never been entirely absent and at the present day reaches as far north as Hatteras, in the warm-water area. It is also a shallow-water shell, living chiefly between tides when the climate is mild enough.

Corals are found fossil in the Caloosahatchee marl, although no reefs are known. The genera comprise *Dichocœnia*, *Meandrina* ("*Pectinia*"), *Cyphastrea*, *Mœandra* (*M. areolata* is abundant), *Siderastrea*, etc. These genera indicate shallow water, a maximum of not over 25 or 30 feet, more probably not more than 10 or 15 feet, and a tropical temperature, 70° F. as a minimum. The assemblage is that of an extensive flat. The corals and mollusks both indicate the same physical conditions prevalent over the areas in which the Caloosahatchee marl was deposited.

In the area of the Nashua marl conditions nearly the same, but with a slightly lower temperature, must have prevailed, for *Chione cancellata* was included in the collections of fossils from every locality except one, and that was a small collection from the east side of St. John's River, 7 miles below Sanford. The opinion may therefore be confidently expressed that seaward, east and south of the Pliocene shore, the Floridian Plateau continued as a shallow submarine bank, having practically the same outline as the present Plateau. The cold water of Miocene time had been diverted offshore, or had at least been replaced by warm waters from the tropical regions, and on this bank arenaceous sediments brought from the north entombed the calcareous remains of organisms that lived on it.

CONFORMITY OF THE PLIOCENE TO OTHER GEOLOGIC BOUNDARIES.

The conformity of the western boundary of the Miocene sediments to the outline established by the Oligocene, Vicksburg and Apalachicola, formations, and to the present outline of the east and south coasts of the State, is observed by the Pliocene deposits, leading to the inference that the material was largely brought from the north by alongshore currents, moving toward the south and southwest. This was not a cold but a warm return or countercurrent similar to the one now moving southward along the Florida east coast.

EVENTS ABOVE SEA-LEVEL.

Important events were taking place on the land on which fluvial and lacustrine deposits were accumulating, while the marine history outlined in the foregoing remarks was being enacted. As this paper is especially devoted to the marine history of the State, the episodes confined to the land surface will not be recounted. They may be found in Dall's chapter on Florida in the Correlation Paper, "Neocene,"[1] by him and Harris, and Matson and Clapp's Preliminary Report on the Geology of Florida.[2]

UPLIFT AT THE CLOSE OF THE PLIOCENE.

Toward the close of the Pliocene deposition the Plateau mass again began an upward movement, as was evidenced by the shoaling in the Caloosahatchee area and the formation of fresh-water ponds. This upward movement continued until extensive areas of the Pliocene sea-bottom were lifted above sea-level.

PLIOCENE-PLEISTOCENE INTERVAL.

The history of this interval unfortunately is not so clear as is desirable. The shoaling of the Pliocene sea and the rise of former sea-bottom was made evident in the preceding paragraph. Data are deficient for a definite estimate of the amount of the emergence.

Professor Shaler, because the Vicksburg limestone has lost its salt water to a depth of a thousand feet, postulated an elevation of at least that amount.[3] Matson in criticism of this conclusion says:

> The deep wells all penetrate the limestones of Vicksburg age, and hence it is the beds of that age which have been drained of salt water. As a portion of these beds have been above sea-level since Oligocene time, the salt water may have been removed before the Pleistocene. The magnitude of the emergence is not necessarily so great as 1,000 feet, because, given the necessary chance for escape, the salt water would probably be displaced by fresh water, provided the surface was high enough to afford a small hydrostatic pressure. The absence of impervious beds of clay above the submarine portion of the Oligocene limestones would permit the escape of the water, and hence considerable thicknesses of the older rocks may have been filled with fresh water without being raised much above their present altitude. (Florida Geol. Surv., 2d Ann. Report, p. 169, 1910.)

Two other probable criteria are left. The first is the existence of underground channels from which submarine fresh-water springs issue near the coast. The best known of these springs is one near St. Augustine. Matson and Clapp furnish the following account of it:

> According to Captain E. C. Allen of that city [St. Augustine], the orifice of the spring is about 60 feet across and the depth is about 200 feet. The depth of the sea at the point of emergence is said to be about 50 feet and the water emerges

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[1] U. S. Geol. Surv., Bull. 84, pp. 127–131, 1892.
[2] Florida Geol. Surv., 2d Ann. Report, pp. 133–145, 167, 1910.
[3] Bost. Soc. Nat. Hist., Proc., vol. XXIV, p. 584, 1890.

with force enough to cause a distinct convexity of the surface during calm weather. According to some authorities, it is difficult to row a small boat across the surface above the spring on account of the outward movement of the water from above the orifice.

These springs can scarcely be older than the age here assigned them, otherwise they would have been filled by sediments. During this uplift, it appears the main drainage lines north of Lake Okeechobee were determined. It is known that the St. John's River channel has a depth of 65 feet below mean tide opposite Jacksonville.[1]

The precise date of the cutting of the submerged channel at the mouth of St. John's River has not been determined and is here only tentatively referred to the interval between the deposition of the Pliocene and Pleistocene.

That there was uplift in this interval is indisputable. The available evidence does not suggest that it was over 200 feet.

Accompanying this oscillation, either with the uplift or the subsequent depression, there was deformation. Pliocene fossils occur at a depth of 150 feet in Lake Tohopekaliga and it is overlain by at least 100 feet of Pleistocene deposits—perhaps 150 feet. As the elevation of the land surface at Kissimmee at the northern end of this lake is 60 feet, the Pliocene is 90 feet below sea-level. The Pliocene at De Leon Springs on the north is between 20 and 40 feet above sea-level; along the Caloosahatchee River 6 to 12 feet. The Pleistocene in the vicinity of Kissimmee fills a depression in the surface of the Pliocene to a depth of at least 100 feet, while it is thin along the Caloosahatchee and also at De Leon Springs. The thickening of the deposits near Kissimmee seems to indicate that a Pliocene syncline existed at the time of this deposition, and that there was a very gentle anticlinal ridge, or swell, parallel to the east coast, and a second similar gentle swell extending north from the Caloosahatchee west of Kissimmee River, between it and Peace Creek. Haines City occupied the northern end of this ridge. Between these two gentle anticlines is the shallow syncline occupied by the Kissimmee Valley. The eastern anticline was one of the agencies determining the location of St. John's River. It seems probable that there was a third gentle fold between Peace River and the west coast.

These structural features have their axes parallel to the axis of the Peninsula. Heilprin, Dall, and Matson and Clapp have all described the folding of the Pliocene strata along the Caloosahatchee. Dall says concerning these folds:

> As the river [Caloosahatchee] is ascended, a close scrutiny shows that it cuts through a succession of gentle waves, gradually increasing in height, inland, whose crests would show a general parallelism with the direction of the Peninsula of Florida, or transverse to the average course of the river. Near the headwaters of the river these waves of elevation rise above the level of the river at low water to a height of perhaps 12 feet at most, and their individual length from one trough to another may average about a quarter of a mile. Though insignificant as flexures, they are interesting as showing that a lateral as well as a vertical thrust has attended the movements of the rocks in this part of the State, a fact which has been questioned. (U. S. Geol. Surv., Bull. 84, p. 143, 1892.)

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[1] Matson and Clapp, *op. cit.*, p. 172.

In February, 1908, I went over the exposures along the Caloosahatchee described by Dall in the preceding quotation, and observed the phenomena. The Pleistocene deposits did not seem to participate in all of the deformation of the Pliocene, pointing to the conclusion that deformation intervened between the two deposition periods. This period of elevation was succeeded by one of depression.

EVENTS OF PLEISTOCENE TIME.

The elevation described in the preceding section is supposed to initiate the Pleistocene, but it is given an individual caption, following the plan of separating intervals of uplift from those of depression. In a region such as the Floridian, which lies outside the area of glaciation, it is not possible sharply to differentiate between the end of the Pleistocene, marked by the final retreat of the glaciers, and Recent, which succeeded their disappearance.

PLEISTOCENE SUBMERGENCE.

The Pleistocene submergence was extensive. Along the western extension and the west coast as far south as Tampa, a narrow border was below sea-level. Proceeding eastward from Tampa Bay, marine Pleistocene fossils are found at the following localities: Six Mile Creek, at Orient Station, Hillsboro County; in a ditch alongside the railroad, 0.125 of a mile south of Manatee Station, Manatee County; North Creek near Osprey; Caloosahatchee River; Kissimmee, in wells at depths of 90 to 100 feet; West Palm Beach, depth 74 feet; 2 miles southeast of Eau Gallie; 4 miles west of Eau Gallie; 0.25 mile and 1 mile north of Mims; Ormond, depth 50 to 56 feet; St. Augustine, at least 30 feet thick, and on St. Mary's River near its mouth.

The localities mentioned indicate that the Pleistocene shore-line lay slightly north of the head of Hillsboro Bay, whence it probably passed south of the southern end of the divide west of Peace Creek, keeping between the 50- and 100-foot contours of the present land area; thence it extended around the southern end of the divide between Peace Creek and Kissimmee River, it followed the west side of the valley of the latter stream, by Orlando, a few miles west of Sanford, and very likely the area east of St. John's River was submerged; certainly the valley of this stream and a coastal fringe from Daytona northward into Georgia were under water. Over half of the present land surface of Florida was below sea-level.

The Pleistocene formations extend down the east coast and thence across the southern end of the Peninsula, exhibiting relations to the old Oligocene nucleus and the present coast line similar to those exhibited by the Miocene and Pliocene, except there is a coastal fringe of Pleistocene on the west coast north of Tampa Bay.

DIFFERENCES IN PLEISTOCENE SEDIMENTS.

The material of the marine Pleistocene varies greatly in different areas. There are shell marls, coquina beds, the Palm Beach limestone, the Miami oolite, the Key Largo and Lostman River limestones, and the Key West oolite, besides deposits of non-fossiliferous sands. There are estuarine deposits along the lower courses of some streams and stream terraces. The respective areas of the various marine deposits will be briefly outlined in order to determine the physical conditions prevailing over those areas during the deposition of each kind of material.

COQUINA.

Coquina is composed of more or less water-worn molluscan shells embedded in a matrix of calcium carbonate and sand. The degree of cementation varies from that sufficient for use as building stone, as in the neighborhood of St. Augustine, to very loose aggregation. The loose aggregations of course grade into shell marls. Coquina occurs along the Florida east coast southward from St. Augustine to beyond Palm Beach, as far as Boca Ratone, forming in its more southern exposures a portion of Sanford's Palm Beach limestone; in fact the Palm Beach limestone extends northward and some of the east coast Pleistocene coquina may be referable to it. Localities at which this kind of rock has been observed are St. Augustine, Ormond, Mims, and Canaveral,[1] north of Palm Beach; and south of the last-mentioned place at Linton,[1] Hillsboro Inlet, and Boca Ratone. Griswold says, concerning the southern localities examined by him:

> About 30 miles north of New River, at Linton, another examination was made. A cross-bedded fragmented rock was abundant, but contained considerable quartz. Coquina was also abundant, and the two rocks were found interbedded.
>
> At Palm Beach and vicinity the Coquina and fine fragmental rock also occur closely associated; the Coquina perhaps predominates. This is about 20 miles north of Linton. * * *
>
> A trip to Cape Canaveral disclosed there a rock which may well represent the fine fragmental rock of Palm Beach and Linton. The quantity of quartz is greater, the quartz grains are larger, and the rock less coherent than to the south.

The following record of a well drilled at Delray by Edwin T. King, for O. Eleasen, shows that the coquina is interbedded with sand.

Record of well at Delray.	Depth.		Thickness.
	Feet.		*Feet.*
Surface sand	0 to	40	40
Coquina	40	43	3
Quicksand	43	108	65
Coquina	108	119	11

A list of a collection of fossils obtained here by Mr. King from a depth of 118 feet is given below.

- Oculina sp.
- Siderastrea radians (Pallas).
- Porites divaricata Le Sueur.
- Cidaris tribuloides Lamk.
- Tornatina bullata Kiener.
- Terebra dislocata Say.
  - dislocata var. indenta Conrad.
  - protexta Conrad.
- Terebra concava Conrad, var., may be new. x
- Conus floridanus Gabb.
- Drillia digitalis Reeve.
- Oliva reticularis Lam. var.
- Olivella mutica Say.
- Marginella opalina Stearns.
- Latirus brevicaudata Lam. ? x

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[1] Griswold, Mus. Comp. Zool., Bull., vol., XXVIII, p. 59, 1896.

Murex rufus Lam.
Sistrum sp., recent on Florida east coast.
Engina turbinella Kiener ? x
Columbella pulchella Kiener.
mercatoria Lam.
Colubraria lanceolata Menke.
Strombus, young, probably pugilis Linn.
Erato maugeriæ Gray.
Trivia quadripunctata Gray.
Omphalius fasciatus Born.
Fissurella alternata Say.
Arca gradata Broderip.
Lucina radiata Conrad.
Chione cancellata Linn.

> All of the identifiable forms perhaps excepting three (those indicated by an "x") are recent. On a percentage basis 90 per cent are surely recent. The horizon is therefore probably old Pleistocene, probably somewhat older than the Miami oolite.

This list will be referred to subsequently.

The prevalence of coquina on the east coast indicates shallow-water beach conditions, with alternations of accumulations of sands and wave-ground shells.

Dall says concerning the west coast:

> There is general opinion among the inhabitants, which was frequently expressed to me in conversation, to the effect that between Tampa and the keys Coquina-rock is only to be found at one place, the mouth of Little Sarasota Bay. But this idea is certainly erroneous, as at every projecting point of the keys along the Gulf shore which we visited, I found traces of this rock, though often not visible above water, and frequently composed more of sand grains than of shell, so that it looks much like wet loaf sugar. (Amer. Jour. Sci., 3d ser., vol. XXXIV, pp. 162, 163, 1887.)

SHELL MARL.

This material is composed mostly of the tests of mollusks, embedded in a matrix of quartz sand with a varying proportion of amorphous and fragmental calcium carbonate. It occupies a very large area extending south and southwest from Daytona from the northern margin of the Pleistocene sea at least as far as the northern margin of Lake Okeechobee, on both its east and west sides. It probably extends as far as the southern end of the Lake on its east side; and certainly does on the west, where there are excellent exposures on Caloosahatchee River.

The fossils listed from the well at Delray represent a shell marl, and give evidence of the southward extension of this class of material along the east coast.

West of Fort Lauderdale, along the southern drainage ditch, there is evidence of intergradation of shell marls and the Miami oolite. First Shaler [1] and later Griswold [2] have called attention to the contemporaneity of coquina and the oolite. The same may be said of the shell marls.

The collections of fossils from the shell marls, made by Dall and Willcox, later by Matson, Clapp, and myself, have given a fair knowledge of the paleontology of these Pleistocene deposits. Dall has published a list of the species obtained from North Creek, near Osprey, Manatee County,[3] and Matson and Clapp have published lists, based on my identifications, of the species from a number of localities. They, however, omitted two important lists, and I insert them in this paper:

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[1] Mus. Comp. Zool., Bull., vol. XVI, p. 143, 1890.

[2] Mus. Comp. Zool., Bull., vol. XXVIII, pp. 55, 56, 1896.

[3] Wagner Free Inst. Sci., Trans., vol. III, pt. VI, pp. 1616, 1617, 1903.

List of Fossils from Oscar Michael's Marl Pit, One Mile Southwest of Daytona (George C. Matson, collector).

- Tornatina canaliculata Say.
- Drillia sp.
- Olivella mutica Say.
- Marginella sp.
- Nassa acuta Say.
- Anachis sp.
- Turbonilla sp.
- Cerithium sp.
- Bittium sp.
  - varians Pfr.
- Crepidula fornicata Say.
  - plana Say.
- Nucula proxima Say.
- Arca pexata Say.
  - transversa Say.
  - ponderosa Say.
- Anomia simplex d'Orb.
- Ostrea virginica Gmel.
- Plicatula spondyloidea Meusch.
- Venericardia radians Conrad.
- Cardium isocardia Linn.
- Venus campechiensis Gmel.
  - mercenaria Linn.
- Chione cancellata Linn.
- Timoclea grus Tuomey and Holmes.
- Anomalocardia caloosana Dall.
- Gemma magna Dall.
- Parastarte trigona Dall.
  - triquetra Conrad.
- Tellina (Angulus) tampaensis Conrad.
- Tagelus divisus Spgl.
- Semele sp.
- Donax variabilis Say.
- Mulinia lateralis Say.

List of Pleistocene Fossils from Labelle, Caloosahatchee River (T. Wayland Vaughan, collector).

- Ameria scalaris Jay.
- Bulla striata Brug.
- Actæon sp.
- Tornatina canaliculata Say.
- Terebra protexta Conrad.
  - dislocata Say.
- Conus floridanus Gabb.
  - proteus Hwass.
- Drillia aff. ulocyma Dall.
- Olivella mutica Say.
- Marginella avena Val.
  - apicina Menke.
- Fasciolaria distans Lam.
- Fulgur perversum Linn.
  - pyrum Dillwyn.
- Melongena corona Linn.
- Urosalpinx floridanus Conrad.
- Nassa vibex Say.
- Columbella rusticoides Heilprin.
- Astyris lunata Say.
- Eupleura caudata Say.
- Strombus pugilis Linn.
- Eulima subcarinata Orb.
- Turbonilla sp.
- Pyramidella sp.
- Cerithium muscarum Say.
  - floridanum Morch.
  - 2 sp. indet.
- Bittium sp.
- Modulus floridanus Conrad.
- Turritella perattenuata Heilprin (probably not in place).
- Calyptrea trochiformis Lam.
- Crepidula aculeata Lam.
  - convexa Say.
- Cryptonatica pusilla Say.
- Neverita duplicata Say.
- Natica canrena Linn.
- Barbatia adamsi Smith.
- Arca transversa Say.
- Plicatula spondyloidea Meusch.
- Crassinella lunulata Conrad.
- Carditamera arata Conrad.
- Venericardia tridentata Say.
- Codakia speciosa Rogers.
- Phacoides sp. indet.
  - nassulus Conrad.
  - pennsylvanicus Linn.
  - multilineatus T. & H.
  - radians Conrad.
  - aff. waccamensis Dall.
  - anodonta Say.
- Montacuta floridana Dall.
- Cardium robustum Sol.
  - isocardia Linn.
- Lævicardium mortoni Conrad.
- Dosinia elegans Conrad.
- Callocardia sayana Conrad.
- Macrocallista nimbosa Sol.
- Transennella caloosana Dall.
- Chione cancellata Linn.
- Anomalocardia caloosana Dall.
- Venus campechiensis Gmel.
- Parastarte triquetra Conrad.
- Tellina sp. indet.
  - sayi Desh.
- Tellidora cristata Recluz.
- Macoma sp.
- Semele purpurascens Gmel.
- Mulinia lateralis Say.
  - sapotilla Dall.
- Corbula cuneata Say.
  - aff. caloosæ Dall.

As there is intergradation between the fossiliferous marls and the Miami oolite in the vicinity of Fort Lauderdale, as exposed in the drainage ditches to the west of the village, lists of the fossils from there are inserted here.

List of Fossils from near Fort Lauderdale (George C. Matson, collector).

Locality: South drainage ditch, 8 miles from Fort Lauderdale.

Pecten irradians Lam.
Lævicardium serratum Linn.
Chione cancellata Linn.

Locality: 7 miles from Fort Lauderdale, south ditch.

Cerithium thomasiæ Sowerby.
Phacoides pennsylvanicus Linn.
    trisulcatus Conrad.
Divaricella densata Wood.
Transennella caloosana Dall.
Anomalocardia caloosana Dall.
Chione cancellata Linn.
Mœrella sp.

Locality: 6.5 miles from Fort Lauderdale, Florida, northern drainage ditch.

Bulla striata Brug.
Conus proteus Hwass.
Marginella apicina Menke.
Melongena corona Linn.
Cerithidea turrita Stearns.
Pyramidella dolabrata Lamarck.
Strombus leidyi Heilprin. (Hitherto known only from the Pliocene.)
Cerithium muscarum Say.
    thomasiæ Sowerby.
Cerithium prob. littoratum Born, junior.
Modulus floridanus Conrad.
Arca auriculata Lam.
Pecten irradians Lam.
Avicula atlantica Lam.
Cardium isocardia Linn.
Lævicardium serratum Linn.
Phacoides pennsylvanicus Linn.
Semele sp.
Phacoides trisculatus Say.
    amiantus Dall.
Divaricella densata Wood.
Chione cancellata Linn.
Dosinia elegans Conrad.
Anomalocardia caloosana Dall.
Macoma brevifrons Say.
Ervilia (4 lots).
Mœrella sp.

Two warm-water non-reef-building corals, *Siderastrea radians* and *Porites divaricata*, were obtained from the well at Delray, depth 118 feet. This place is slightly north of Hillsboro Inlet, but slightly south of the latitude of the Caloosahatchee exposures and considerably south of those around Charlotte Harbor. It appears that in Recent time the waters may have been cooled somewhat more.

SOUTHWARD EXTENSION OF BURIED SANDS.

The intergradation between both the coquina and the Miami oolite with arenaceous shell marls has already been described, also the interbedding of siliceous sands with the predominantly calcareous material has been mentioned. On the east coast south of Delray, the surface, except a surficial coating of sand, is formed by the Miami oolite and the Key Largo limestone; on the west coast by the Lostman River limestone; and that of the keys west of Bahia Honda by the Key West oolite. Beneath these limestones, however, are sands probably in part Pleistocene and in part Pliocene in age.

The following well records will show the southward extension of these buried sands:

	Depth.		Thickness.
Well at Fort Lauderdale; P. N. Bryan, owner; record furnished by Edwin T. King:	*Feet.*		*Feet.*
Sand	0 to	2	2
Oolitic limestone (Miami oolite)	2	14	12
Sand	14	30	16
Limestone	30	30.5	0.5
Sand and gravel	30.5	68.5	38
Hard white limestone	68.5	69.5	1
Sand and gravel	69.5	100.5	31
Limestone, in alternating harder and softer layers	100.5	108.5	8
Well at Dania; property of town; record furnished by Edwin T. King:			
Surface sands	0 to	6	6
Oolitic limestone (Miami oolite)	6	40	40
Blue mud with some gravel	46	80	34
Hard limestone	80	88	8

At Miami, "samples from the wells of the water company show that the oolite loses its typical appearance a few feet below sea-level and rests on an irregularly cemented aggregate of shell fragments and quartz sand."[1]

The record of the well at Marathon, Key Vaca, revealed quartz sand below 155 feet (see page 128). Some of these sands may be Pleistocene.

Sands underlie the Lostman River limestone at a depth of 30 feet at Everglade postoffice.[2]

Sanford reports a thickness of probably less than 50 feet for the Key West oolite[3] and mentions over 200 feet of quartz sand beneath it[4] on Big Pine Key.

These records show sand beds underlying the Pleistocene limestones as far south as Big Pine Key; some of the sands, the more northerly, are surely Pleistocene, the more southerly may be partly Pleistocene and partly Pliocene.

THE FLORIDA OOLITES.

The presence of two oolitic formations in Florida, the Miami and Key West oolites, has been stated on preceding pages (pp. 130, 131) and certain of their characters have already been given, viz.: their geologic age, their general appearance, the structure of the granules, and their areal distribution. As the object of the following remarks is to throw such light as is possible on the origin of these deposits, a brief statement will be made of the views of the principal previous students.

Louis Agassiz[5] in his report for 1851 to Professor A. D. Bache, Superintendent of the Coast Survey, says:

> The main islands of this group (west of Bahia Honda) are very flat, and consist of thin layers of a regularly stratified and somewhat oolitical limestone, evidently formed by deposits of limestone mud.

E. B. Hunt[6] seemed to be of the opinion that the Key West oolite might be partly due to the direct transformation of calcareous mud, or to the transformation of calcareous sand lying above sea-level.

Shaler considered the oolite a coral-reef rock and named that in the vicinity of Miami the Miami Reef.[7] The oolite is distinctly not a coral-reef rock, and Shaler's opinion is to be attributed to the fashion at that time of considering practically all limestone in that area as having been formed through the agency of corals. The differentiation[8] of varieties of limestone had not then progressed so far as at present.

The next important contribution to the subject came from Mr. Alexander Agassiz in his "The Elevated Reef of Florida,[9] with notes on the Geology of Southern Florida by Leon S. Griswold." Mr. Agassiz has presented the salient features of his conclusions as follows:

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[1] Florida Geol. Surv., 2d Ann. Report, p. 212, 1910.

[2] Sanford, *op. cit.*, p. 223.

[3] *Op. cit.*, p. 220.

[4] *Op. cit.*, p. 206.

[5] Mus. Comp. Zool., Mem., vol. VII, p. 19, 1880.

[6] Amer. Jour. Sci., 2d Ser., vol. XXXV, p. 203, 1863.

[7] Topography of Florida, Mus. Comp. Zool., Bull., vol. XVI, p. 143, 1890.

[8] Compare Mr. Agassiz's remarks in his "A Reconnaissance of the Bahamas and of the Elevated Reefs of Cuba in the Steam Yacht *Wild Duck*, January to April, 1893." (Mus. Comp. Zool., Bull., vol. XXVI, p. 179, 1894.)

[9] Mus. Comp. Zool., Bull., vol. XXVII, pp. 29-62, 26 plates, 1896.

> I was quite surprised on examining a bluff about 10 feet in height, extending eastward from Cocoanut Point toward the mouth of the Miami River, to find that it consisted of *æolian rocks* which have covered the elevated reef in many places. On the low shores these æolian rocks are honeycombed and pitted and might be readily mistaken for decomposed reef rocks; but they contain *no* corals. This looks as if the lower southern extremity of Florida, the Everglade tracts, was a huge shallow sink, or a series of more or less connected sinks, into which sand had been blown, forming low dunes which have little by little been eroded, and which former observers had mistaken in some localities for reef rock. The material for these dunes coming from the now elevated reef or the beach rock at a time when it was either a fringing or a barrier reef along the former coast line of Florida, all of which, back of the reef, has little by little been eroded by the mechanical and solvent action of the sea, leaving on the mainland only an occasional outcrop of the elevated reef as observed by Professor L. Agassiz and Shaler. The outer line of reef has also been elevated.

There are in this view several points that need to be emphasized: (1) The Miami oolite is *not* a coral reef rock. (2) It is of æolian origin. (3) In southern Florida a huge sink existed, into which the material of the oolite was blown. (4) The source of wind-blown sand was either the now elevated reef or the beach rock at a time when it was either a fringing or a barrier reef along the former coast-line of Florida. (5) The bays and sounds are due to the mechanical and solvent action of the sea. What is of particular concern here is the supposed æolian origin of the oolite and the source of the material. The discussion of the "huge shallow sink" and the formation of the bays and sounds may be laid aside for the present.

A careful reading of the text of Mr. Agassiz's remarks does not reveal the criteria by which he determined the oolite to be æolian; he has merely given his opinion. In his foot-notes to Mr. Griswold's "Notes on the Geology of Southern Florida," although dissent from Griswold is expressed, still no criteria are given for distinguishing between water-laid and æolian cross-bedded calcareous deposits. At the bottom of page 52 is the statement: "This bluff is a most distinctly marked æolian rock exposure, with characteristic knife-edge stratification." A comparison of plate XV of Mr. Agassiz's report on the Bahamas with plate XIX of Griswold's "Notes" will show considerable similarity in structure of the Bahaman and Floridian materials.

Griswold in his "Notes on the Geology of Southern Florida," already cited, says concerning the origin of the oolite:

> The low undulations of the land surface in the pine belt can scarcely be accepted as evidence of former dunes. They would well accord, however, with the inequalities of a sea floor like the present one between the keys and the mainland. The cross-bedding and oolitic structure favor neither water nor wind as the primary agent in the construction of the rock. Therefore, since the land appears to be very young, being almost without soil and surface drainage ways, the topography favors an origin for the limestone in water.

Sellards has published the opinion that the Miami oolite is a marine formation.[1]

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[1] Florida Geol. Surv., 1st Ann. Report, p. 22, 1908.

Vaughan published the next opinion on the origin of the oolite.[1] According to him it was formed as a water-laid deposit, probably behind a seaward barrier. He states:

> The reasons for this opinion are that numerous marine fossils are found in the oolitic material, the two valves of bivalve mollusks are frequently in place, showing no damage by attrition, and fossil corals which exhibit no indication of having been rolled or waterworn were found. The marine fossils found in the oolite had evidently lived in the water during the formation of the oolite. On the surface of Big Pine Key original mud cracks formed by desiccation were observed and photographed.

The last published opinion is that of Sanford, who says:

> The characteristics of the calcareous sands and marls accumulating about the keys and in the Bay of Florida, and the distribution, topographic relief, bedding, contained fossils, and structure of the Key West and Miami oolites indicate that the latter were limy muds, with a varying proportion of lime sand and a little quartz sand, which accumulated on the bottom of shallow bays or lagoons, where in places the water was relatively still, in places agitated by waves and currents strong enough to build up and level off banks and bars. (Florida Geol. Surv., 2d Ann. Report, p. 222, 1910.)

Two theories have been proposed for the origin of the Florida oolites, viz: (1) that of Alexander Agassiz, who considered that the deposits were of æolian origin and were made in a "huge shallow sink"; and (2) that of Louis Agassiz, which considered them of aqueous origin.

In the following account an attempt will be made to assemble the data bearing on these two theories.

The macroscopic and microscopic structure of the oolite granules shows them to be composed of concentric shells of calcareous substance accumulated around a nucleus in some instances calcareous, in others siliceous. This structure is characteristic of concretions, but the problem of the origins of concretions is raised, and a definite answer is not obtained as to whether the material is of subaqueous or subaerial origin. However, it may be mentioned that the specimens I collected on Cat and Gun keys, Bahamas, distinctly showed their detrital nature, while the typical Miami and Key West oolites are distinctly not detrital. But as I did not visit a great number of the Bahaman Islands and have seen none of the Bermudas, I have not the necessary information for a general comparison.

The topography of the surface of the Floridian oolites is not of criterional value, as gentle undulations may be produced under the water or the air, or by slight folding. Here again, however, the flat upper surface of the Key West oolite is more suggestive of water-laid than wind-blown deposits.

The strong cross-bedding of the Miami oolite has been mentioned in the quotation from Griswold. This has been interpreted by Mr. Agassiz as evidence of æolian action, and it is stated by Griswold that as evidence it is not decisive.

In order to illustrate bedding presumably due to wave and æolian action, separate or combined, a series of photographic illustrations are introduced. Plate 13, fig. *a*, illustrates an exposure on Gun Key, Bahamas, eastern side, below the lighthouse. This is probably an æolian sandstone, and exhibits cross-bedding very well. Plate 7, fig. *b*, represents the western beach of Loggerhead Key, Tortugas, looking northeast. It shows indurated calcareous sandstone along the water's edge and loose calcareous sands higher on the beach slope. Note the continuity of the slope of the lower indurated with that of the higher unconsolidated material.

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[1] Carnegie Institution of Washington, Year Book No. 7, p. 133, 1909.

The material represented in all of the illustrations mentioned is of detrital origin, and illustrates bedding by shore waves and the wind. Plate 14, fig. *a*, illustrates cross-bedding in a water-laid deposit.

Plate 13, fig. *b*, represents exposures of the Miami oolite. The sharp cross-bedding is brought out, but the rock occurs in distinct ledges. This massive bedding with the cross-bedding of the smaller divisions is suggestive, and it should be emphasized that the oolite granules are not similar to the detrital sands composing the Bahaman and Tortugas exposures.

The data so far presented indicate an individuality of the Floridian oolite areas different from that of the other areas discussed, although as yet definite criteria for determining the conditions under which the oolite was formed have not been advanced. Cross-bedding may be due to current, wave, or wind action, and the three processes may be more or less coöperative.

Illustrations of the surfaces of two oolitic keys bear on the solution of the problem, viz: Plate 14, fig. *c*, which represents Summerland Key; and plate 15, fig. *a*, a view of Boca Grande Key, show remarkably flat surfaces, not in the least suggestive of dunes. On Big Pine Key the surface of the oolite shows mud cracks from drying (plate 14, fig. *b*). Fortunately the oolites are rather rich in fossils.

Fossils from the Miami Oolite.[1]

Locality: Golf Ground, Miami.

Cyphastrea hyades (Dana).
Conus floridanus Gabb.
Columbella mercatoria Lam.
Cerithium muscarum Say.
        littoratum Born.
Arca gradata Broderip.
Glycymeris pectinata Gmelin.
Avicula atlantica Lam.
Lævicardium serratum Linn.
Codakia orbicularis Lam.
Phacoides pennsylvanicus Linn.
Chione cancellata Linn.

Locality: Kronkheit-Offer Quarry, Miami.[1]

Siderastrea radians (Pallas).
Strombus gigas Linn.
Livona pica Linn.

Correlation.—The species are all Recent, and the age of the oolite is therefore Pleistocene.

Locality: Buena Vista.[1]

Mellita sexforis Lamarck.

Fossils from the Key West Oolite.

Locality: Big Pine Key (collected by Samuel Sanford).

Mussa (Isophyllia) sp.
Encope michelini Agassiz.
Terebra dislocata Say.
Strombus pugilis Linn.
Cardium isocardia Linn.
Lævicardium serratum Linn.
Phacoides pennsylvanicus Linn.
Divaricella densata Wood.

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[1] The fossils from these localities were presented by Dr. J. N. McGonigle, of Miami.

Dolium galea Linn.
Natica canrena Lam.
Neverita duplicata Say.
Pecten irradians Lam.
Tellina radiata Linn.
Metis intastriata Say.
Macrocallista maculata Linn.
Chione cancellata Linn.

Locality: Torch Key, eastern side, along railroad embankment (A. G. Mayer and T. Wayland Vaughan, collectors).

Siderastrea radians (Pallas).
Fulgur perversum Linn.
Dolium galea Linn.
Cerithium thomasiæ Sowerby.
Cerithium littoratum Born.
Modulus modulus Linn.
Pecten gibbus Linn.
Cardium isocardia Linn.
Phacoides pennsylvanicus Linn.[1]
Divaricella quadrisculata Orb.
Dosinia elegans Conrad.[1]
Chione cancellata Linn.
Tagelus divisus Spengler.
Semele cancellata Orb.

[1] The two valves are still adherent.

All of the species are Recent, and the geologic age is Pleistocene.

The fossils show no attrition, and the two valves of some of the pelecypods are still in their natural position. These fossils must have remained embedded in the material in which they were more or less embedded when alive. In other words, the surrounding oolite must have originated as a water-laid deposit.

Mr. Agassiz, in his theory of sands blowing into sounds behind the keys and still preserving the character of wind-blown deposits, could scarcely have had it in mind that the sounds or hollows were filled with water, as it could not be expected that sand blown into water, and deposited through it, would preserve the same structure as if subaërially deposited.

To summarize the conclusions pointed by the data presented in the foregoing remarks:

1. The fossils show that the oolite is a water-laid deposit formed in shallow water, a few fathoms, or more probably only a few feet, in depth.
2. The cross-bedding shows it was formed in areas of moderate and variable currents.
3. The topography shows it was formed on flats.
4. The Miami oolite has been elevated above the water-level a sufficient time for it to have suffered considerable denudation; while the Key West oolite preserves its original flat surface with intact mud cracks.

One object in view in collecting bottom samples within the keys was to obtain light on the problem of the origin of the oolites, and the effort had a negative result. A study of the oolites themselves seems to have answered the question. While on Boca Grande Key, on the beach of which oolite occurs, I obtained a suggestion that was perhaps of value. It seems to me that the shells of an oolite grain accumulate around some nucleus by the gentle rolling of that nucleus on a bottom on which calcium carbonate is being precipitated. There is no evidence that oolite is being formed behind the keys east of Bahia Honda, but I think it very likely that it is forming around some of the more westerly keys.

Two geological formations of marine origin remain to be discussed: the Lostmans River and Key Largo limestones. The former was described on page 130; the latter on pp. 130, 131.

LOSTMANS RIVER LIMESTONE.

Sanford says concerning the origin of the Lostman River limestone:

> Origin:—Willis has suggested that the rock at Lostmans River was perhaps formed by the deposition of crystallizing calcium carbonate from the presumably limy waters of the Everglades. While there can be no doubt that deposits of marl are now accumulating along the coast, the present hardening of marl to crystalline limestone or the direct deposition of such limestone is not established. As the writer has stated, the bed rock of the western coast, wherever soundings have been made, whether in the Everglades, on swamp islands, along the coast, or in the numerous creek channels, seems to have a gentle slope toward the Gulf. The rock is no farther below water-level in the swamp than in adjacent channels; moreover, the rock surface in channels where the current runs strongly is full of crevices, is extremely rough, and is evidently being eroded. Loose fragments that have been detached by solution are found, not only near the mouths of rivers, but at their heads, on the bare rock, under marl, and under vegetable muck. Another fact that impairs the deposition and crystallization theory is the character of the Everglades water. Most of the marl in the Ten Thousand Islands has come from the ever-dirty shallows of the Gulf. The dark limestones below water in the creeks are the same as those that outcrop above water a short distance away, and a recent crystallization from solution of those is hard to understand.
>
> The limestone on Lostmans River, though containing calcite crystals an inch long, is not greatly different from other limestones of southern Florida; removal, deposition, and crystallization of carbonate of lime are characteristic of the region.[1]
>
> The limestone, from its petrographic and paleontologic characteristics, is a shoal-water deposit of marl and limy sand, containing shells of living species of mollusks, that has been solidly cemented and subjected to conditions favoring crystalline growth. This growth may be in progress. (Florida Geol. Surv., 2d Ann. Report, pp. 224, 225.)

KEY LARGO LIMESTONE.

The Key Largo limestone is so closely similar to that being formed by the present reefs, that it is safe to postulate the same physical conditions for the fossil as for the living reefs. They were formed in water having a maximum depth of 18 to 20 feet, a minimum temperature of 70° F., and lay just landward of the current of the Florida Straits. They were separated from the inner bank by a deeper channel, comparable to the present Hawk Channel, and now represented by the bays and sounds between the keys and the mainland.

SURFACE SANDS OVERLYING THE MARINE PLEISTOCENE.

The surface of the Pleistocene fossiliferous deposits is usually overlain by a coating of surface gray or white sand, of variable thickness, from a few inches to several feet. Most probably this sand was originally a marine deposit, laid down as the sea shoaled. Wind has been active in distributing some of it over the land surface, as is attested by the dunes of the east coast as far south as Pine Island in the Everglades, back of Fort Lauderdale,[2] and on the west coast as far south as Caximbas Pass.

UPLAND GRAY SANDS.

The suggestion may be ventured that a portion of the upland gray sand, which covers all pre-Pleistocene formations and has puzzled so many geologists, may be sand of beaches formed as the successive seas shoaled and then blown inland by winds. According to this theory the surface sands would belong to no one geological period, but would represent all the periods since the Vicksburg. Some of these surface sands are undoubtedly residual deposits.

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[1] For references to calcite crystals in other Pleistocene limestones of Florida, see pp. 130, 131.

[2] Florida Geol. Surv., 2d Ann. Report, pp. 224, 225.

RIVER TERRACES AND OTHER PLEISTOCENE FORMATIONS.

River terraces are present in Florida, as in the valley of St. John's River, where a well defined one rises 20 to 30 feet above tide,[1] and there is evidence of their occurrence along other streams, but in the absence of detailed topographic maps they can not be satisfactorily discriminated.

Other Pleistocene formations are aggregates of the shells of the fresh-water mollusk *Planorbis*[2] and masses of the tubes of the marine mollusk *Vermetus negricans.*[3]

SUMMARY OF PLEISTOCENE HISTORY.

In the preceding discussion of the marine Pleistocene formations of the Peninsula of Florida, their salient characteristics, their distribution, and the conditions under which they were formed have been given. These data permit a general statement of the conditions prevalent over the submarine portion of the Plateau, with some deficiency in precision due to a lack of accurate knowledge of succession and synchrony between all of the deposits. There are undoubtedly several horizons in the Pleistocene. The material from west of Fort Lauderdale seems, from the fossils, to be older than the Miami and Key West oolites. The material in the Delray well, depth 118 feet, may be older than that west of Fort Lauderdale. Additional detailed stratigraphic and paleontologic work on the Pleistocene deposits is needed.

The Pleistocene shore-line has already been outlined. Seaward of this margin the entire Peninsula was submerged, but to no great depth; very likely, unless in channels or entrants, in no place did the depth of the water exceed 50 feet. During a portion of the period of submergence the sea-bottom was gradually lowered and deposition kept pace with the sinking.

Shell marls were deposited over practically the entire surface of the submerged platform north of the present southern margin of Lake Okeechobee. The fauna indicates for this region a warm temperature; however, it was a few degrees cooler than that of the present east coast south of Key Biscayne. Arenaceous sand was brought from the north and carried practically to the southern margin of the Plateau, but in the later Pleistocene in much diminished quantities south of Miami. This sand came partly from the mainland to the north and partly by southward-moving shore currents, which must have been warm return-currents, as the fauna was characteristic of warm water. Shell-banks formed by wave-wash accumulated on the east coast from St. Augustine to at least 20 miles below Palm Beach, and are now coquina. These deposits may have been formed along the margin of the bank as it was elevated. Similar coquina beds appear to have been formed on the west coast.

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[1] Matson and Clapp, Florida Geol. Surv., 2d Ann. Report, p. 39, 1910.

[2] Matson and Clapp, *op. cit.*, p. 153.

[3] Matson and Clapp, *op. cit.*, p. 154.

South of the latitude of the present southern end of Lake Okeechobee, limestones were the prevalent geologic formations, and in this region the four limestone formations of south Florida were formed, all in shallow water. On the southwest it was the Lostman River limestone; along the southeastern and southern margin coral reefs grew and formed the Key Largo limestone. Behind the line of reefs was a channel comparable to the Hawk Channel of present time. East of the Lostman River limestone, in shoal water, agitated by strong currents, the Miami oolite accumulated. Whether this oolite was formed previous to the formation of the Key Largo limestone, or whether the two are contemporaneous, is an unsolved problem. Westward of the Key Largo limestone, oolite was forming on a shallow bank, later to form the group of keys from the Pine Keys to Boca Grande.

The temperature of this portion of the ocean and the direction of the currents were practically as to-day.

Pleistocene time was closed by an uplift of the Plateau—the uplift evidently being accompanied by deformation, as the elevations of the surface of the marine Pleistocene are by no means the same. Those in the central portion of the Peninsula are greater than toward the south, and the east coast is higher than the west. There is evidence of a slight ridge on each side of Lake Okeechobee, the eastern ridge being the higher.

J. O. Wright, Supervising Drainage Engineer of the Department of Agriculture, in a report embodied in the Report of the Special Joint Committee of the Legislature of Florida on the Everglades of Florida,[1] gives the mean water-level in the Okeechobee Lake as 20.5 feet above tide, level at low stage about 19 feet; the greatest depth at low water is 22 feet, or the bottom is 3 feet below sea-level; the average depth is 12 feet, or the bottom is 7 feet above sea-level. Heilprin says concerning the depth of the Lake:

> We took numerous soundings all along our course, probably fifty or more, which gave an average depth ranging from about 7 to 10 feet. The deepest sounding made on the diagonal connecting Taylor Creek and the mouth of the canal, about 4 miles southwest of Eagle Bay, gave 15 feet, but this is the only instance when we obtained this depth. (Wagner Free Inst. of Sci., Trans., vol. 1, p. 41, 1887.)

Accurate geologic information on the bottom of the Lake is scanty, but as it is surrounded by marine Pleistocene, the surface deposit on the bottom may be safely inferred to be Pleistocene. As Pleistocene occurs at higher elevations on both the east and west sides, the conclusion is pointed that the Lake lies between gentle anticlines, one toward the east, the other westward, and there may have been somewhat greater elevation between its southern end and the southern shore than in the area of the Lake itself, producing a shallow synclinal hollow.

In the vicinity of Kissimmee the amount of elevation was 60 to 70, or perhaps 100 feet; of Miami, 40 to 50 feet; along the coral reef keys, 10 to 15 feet; along the Caloosahatchee, near Fort Thompson, perhaps 30 to 40 feet; near Osprey, less than 30 to 40 feet; along the keys west of Bahia Honda, perhaps 10 to 20 feet. Along the west coast in places there may have been very slight elevation.

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[1] Tallahassee, Florida, 1909.

The details of these differential earth-movements have not been worked out, and until accurate topographic maps are available and more thorough studies of the stratigraphy and structure have been made, it will not be possible to decipher them.

This uplift may have been intermittent, or there may have been oscillation. The presence of terraces along some stream indicates one or the other. The amount of the elevation closing the main Pleistocene deposition was probably greater than that now shown by the land surface, it being followed by a slight depression, as is evidenced by the drowned valleys of recent times; that of St. John's River is an instance.[1]

RECENT.

The events closing Pleistocene time gave the Plateau its present configuration, and although no attempt will be made to recount in detail Recent phenomena, the development of both the present coral reefs and the interior swamps of the Everglades may be mentioned. The reefs developed next the pure ocean waters just inside the 10-fathom curve, and the Everglades were formed on the flat, imperfectly drained area south of Lake Okeechobee.

The geologic history of the Marquesas and Tortugas is reserved for future consideration. The present surface above sea-level of these two groups of islets seems to be geologically Recent. They are mostly or entirely composed of organic detritus and calcareous material drifted westward along the southern margin of the Floridian bank, as both Hunt and A. Agassiz have contended. However, important geologic details remain to be worked out for each group.

RÉSUMÉ OF THE GEOLOGIC HISTORY OF THE FLORIDIAN PLATEAU.

The agencies which originally shaped, and subsequently dominated, the development of the Plateau, were of two kinds: (1) those that cause warpings of the earth crust; (2) those resulting in the deposition of material on the sea-floor, viz: corrosion and erosion of the land surface above sea-level, transportation to the sea, transportation and deposition of land-derived material in the sea, and organisms which added their skeletal remains to the material of inorganic origin.

The Plateau existed in Vicksburgian, Lower Oligocene, time, projecting as a submarine platform from the southeastern corner of the continental shelf and extending at least to its present southern limit. The forces by which this older Oligocene platform was formed at present can only be the subject of speculation. It was due to some fold of the ocean-bottom, perhaps in some way connected with the angle of the Piedmont area in central Georgia.

The water over this Plateau was shallow, probably in no place 100 fathoms deep; the bottom temperature was between 70° and 80° F.; tropical currents passed over its surface; deposits of both terrigenous and organic origin accumulated on it ranging in thickness from 100 to 200 feet near shore to the north to over 1,000 feet near its southern margin. As the water was shallow, the sea-bottom must have been gradually depressed while the material accumulating on its surface was being deposited.

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[1] Matson and Clapp, *op. cit.*, p. 172.

At the close of Vicksburgian time the Plateau was elevated and areas of its surface were subjected to subaerial denudation, as is attested by the erosion uncomformity along the contact of the basal Apalachicola with the underlying Vicksburg sediments.

Apalachicolan time needs separation into two stages, an earlier, represented by the Chattahoochee, Hawthorne, and Tampa formations, and a later, represented by the Alum Bluff formation. The areal extent of the deposits of the earlier stage was not so great as that of the Vicksburg deposits, indicating the later was not so extensive as the previous submergence. The northern shore-line was seaward of that of the Vicksburg Group; it seems probable that a small island existed in the sea in what is now the northeastern corner of Marion County, and in other areas the sedimentation over the Vicksburg deposits was thin. Along the western coast of Florida the Vicksburg formations were being gently folded, and a dome-like structure was developing southward.

The Plateau, in early Apalachicolan time, had practically the same outline as at present; the depth of water north of Tampa was probably in no place over 100 feet. Coral reefs were present in southern Georgia, across the base of the present Peninsula, and around Tampa; the temperature was tropical, the minimum for the year being at least as high as 70° F.; the main movement of the ocean water was from the tropics; the sediments consisted to a lesser degree of organic débris, and were predominantly of terrigenous constituents.

In the later stage of Apalachicolan sedimentation, the island of Oligocene lying west of the present longitudinal axis of the Peninsula, here named Orange Island, had by further uplift increased in size and was separated from the mainland to the north by the Suwanee Strait. There was differential earth-movement, the sea-bottom being depressed around Orange Island and between it and the shore of the mainland to the north, permitting additions to the thickness of Apalachicola sediments. During this later stage of the Apalachicola the oceanic waters of the region gradually cooled and coral reefs disappeared. The sediments were mostly of terrigenous origin and were laid down in shallow water.

This period of deposition was succeeded by one of uplift and subaërial erosion, the Apalachicolan-Miocene Interval, after which was another, the Miocene, subsidence. This subsidence was not so extensive as that of the preceding deposition period, and although it seems probable it is not positively proven that the Suwanee Strait was again open water, the Miocene deposits did not extend so far inland as the margin of the Apalachicolan Sea, and there were extensive land areas west of the present longitudinal axis of the Peninsula. The Plateau had approximately its present outline, and thick deposits of arenaceous sands were formed practically to its southern limit, certainly as far south as the locality of Key Vaca; the sea was shallow, perhaps 25 fathoms is a safe maximum; there was depression coincident with deposition on the east coast; the waters were cold, a cold inshore countercurrent lowered the temperature to that of the region between Cape Hatteras and Long Island. This southward-moving countercurrent, aided by winds and waves, is largely responsible for the greater thickness of sediments on the east than on the west coast, and it is the forerunner of the series of countercurrents so important in the later history of the region. Toward the close of the Miocene period uplift was again initiated, and the Suwanee Strait, should it not have been previously closed, was then assuredly above sea-level, and the north and south Trail Ridge was formed. The uplift seems to have been greater on the east than on the west, for no Miocene is above sea-level from Levy to Pasco counties on the west coast, while submerged Miocene is apparently present off the mouth of Tampa Bay.

The Pliocene submergence was extensive, over half of the present land surface of the Peninsula lying below sea-level. The submergence of the present land surface along the east coast extended down the west side of St. John's River valley, and entirely across the median portion of the Peninsula northwest of Lake Istokpoga. No known marine Pliocene occurs on the west coast north of the Charlotte Harbor localities. The general outline of the Plateau remained as it was in Miocene time; the water was shallow, usually between 20 and 30 feet in depth; the temperature was tropical in the southern, the Caloosahatchee area; and warm, but slightly cooler in the northeastern area, in the vicinity of Nashua. The oceanic current over the Pliocene bank must have been a warm countercurrent—a countercurrent because it brought sands from the north and deposited them on the Pliocene submarine bank.

While the Pliocene marine deposition was taking place important lacustrine and fluvial deposits were accumulating on the land surface above the sea.

Pliocene deposition was closed by another uplift of the Plateau. Data for a precise estimate of the height of the land during this emergence are not available, but the evidence obtainable indicates that it was not over 200 or 250 feet as a maximum, and as the previous movements of the Plateau were differential it is most probable that only portions were subjected to oscillations so great. Accompanying this oscillation a shallow syncline was developed along the axis now occupied by the Kissimmee River, with low anticlines on each side. Probably a third anticline was developed west of Peace Creek. The axes of these folds are parallel to the longitudinal axis of the Peninsula, and have been important in influencing the drainage courses of middle Florida.

The Pleistocene submergence was as extensive as that of the Pliocene, all Pliocene areas, perhaps, but not probably, excepting one between St. John's River and the east coast, being resubmerged, and there is a border of Pleistocene on the west coast and the western extension where Pliocene is not now known. The Plateau throughout Pleistocene time preserved its general outline. Shallow-water conditions prevailed over its entire submerged portion. In no place were the known deposits laid down in water much deeper than 50 feet, and usually from barely below sea-level to 25 or 30 feet. The temperature north of the latitude of the southern end of Lake Okeechobee was slightly cooler than in Pliocene time, but it was still warm. In this shallow, warm sea sediments of diverse kinds were deposited. Sands and shell marls are probably the most extensive, forming widespread deposits over almost the entire submarine bank. The sands extend beneath the limestone formations as far south as Miami, and perhaps to the southern keys. Along the more northerly portions of the bank coquina accumulated. Along a curve, first southward and then bending westward, from Biscayne Bay, a coral reef flourished, separated by a channel of deeper water from the main bank, on which the Miami oolite was forming or had formed in shoal water strongly agitated by currents. Along the southwestern portion of this bank, also in shoal water, the Lostmans River limestone accumulated. West of the coral reef, on an extensive flat in the shoal water over them, the Key West oolite was formed. Toward the close of the Pleistocene the previously formed sands, marls, and limestones southward beyond Miami received a thin coating of siliceous sand. Contemporaneous with this purely marine work, the terracing of rivers to the north was taking place.

Pleistocene time was closed by an uplift, which may have been intermittent or may have been accompanied by oscillations. There is some evidence of slight depression since the principal uplift. After this uplift the living coral reefs developed, the Everglades were formed, and the Florida of to-day was the result.

This summary will be closed by an account of the rôles played by deformation and ocean currents in the history of the Plateau.

DEFORMATION.

The Floridian Plateau owes its origin to a fold of the sea-floor in pre-Oligocene, probably Eocene time, producing a platform on which sediments during the later geologic periods were laid down. The whole earthmass, since the origin of the platform, has been subjected to a succession of deformations due to compression between forces acting from the east and west, resulting in the axes of the gentle folds being coincident in direction with the longitudinal axis of the Plateau, and to downward and upward tilting around a landward fulcrum. The initial uplift with deformation took place, as nearly as can be determined, toward the close of the Vicksburgian deposition period. The Vicksburg nucleus lay nearer the eastern than the western margin of the Plateau surface, and was roughly dome-like in form, but with a longer north-and-south than east-and-west axis. The subsequent growth of the Peninsula was by filling the channel between the island of older Oligocene (Vicksburg) rocks and the mainland, and by growth eastward and southward from it. There was little or no westward growth. There was additional deformation in later Oligocene (Apalachicolan) time, between the Apalachicolan and Miocene deposition periods, between the Miocene and Pliocene, between Pliocene and Pleistocene, and succeeding the Pleistocene deposition. The result of each of the series of deformations was to add, beginning with the Miocene-Pliocene member of the series, one or more anticlinal swells with intermediate synclinal depressions to those that preceded, the additions above sea-level always taking place toward the east, and at each elevation the uplifting was propagated southward. The continued effect of all the uplifts was to elevate the eastern portion of the Plateau above the western, or there has been elevation on the eastern side of the Plateau coincident with stability or even slight depression on the western side.

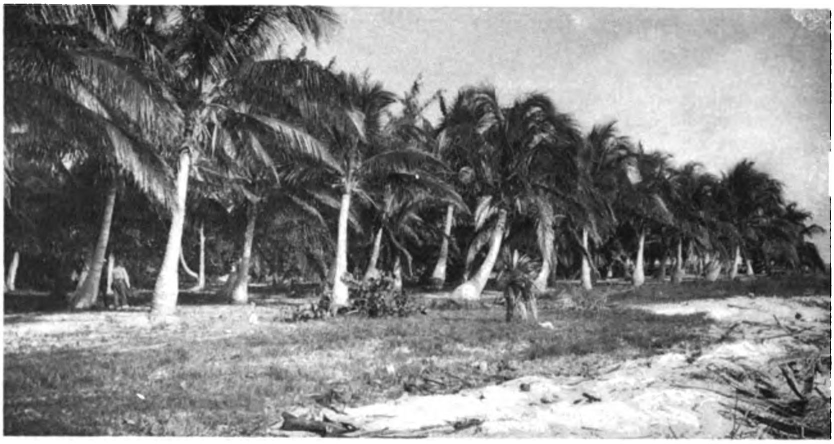
CURRENTS.

The importance of currents in shaping the land area of Florida has been emphasized in several sections of the preceding discussion. Before the history of the currents of the region can be thoroughly understood it is necessary to know the history of the Hatteras axis of North Carolina. The present Florida countercurrent seems due partly to the impingement of the Gulf Stream against the Hatteras projection, resulting in a portion of the waters being deflected southward along the coast instead of continuing their northward journey. The Hatteras axis has existed as a dividing line between depositional areas apparently since middle Cretaceous time, and it has been either a region of shoal water, or occasionally a land area, since later Eocene time. The Vicksburgian and Apalachicolan seas were both warm, tropical or subtropical in temperature. It is not definitely determinable at present whether the warmth of these waters was due to currents directly from the Tropics or to warm return currents produced by the northward flowing Gulf Stream having a portion of its waters diverted southward by impinging against a salient from the more northerly land area.

In Miocene time it is definitely known that a cold inshore current found its way southward to Florida and westward to Pensacola. This current may be due to the Miocene submergence of the Hatteras area sufficiently lowering the sea-bottom off Hatteras to permit the Gulf Stream to continue its course unobstructedly northward. Should this hypothesis be correct a re-examination of the faunas of the Miocene deposits of northern North Carolina and Virginia, and those of southern North Carolina (the Duplin marl), South Carolina, Georgia, and Florida, with reference to synchrony may be necessitated. The Miocene southward current transported quantities of terrigenous material and deposited it on the eastern border of the Floridian Plateau.

Since Miocene time there have been constantly return currents of warm water (however, not so warm as the Gulf Stream), and they, aided by winds and tides, have deposited terrigenous material on the eastward side of the existing land areas, sweeping a portion of it to the southern end of the Plateau. These currents were active during Pliocene and Pleistocene times, and are still active to-day.

The shape of the upper surface of the Floridian Plateau, the land area of its eastern side, the arrangement of the geologic formations of successive ages, the directions of the stream courses, and the contour of the present coast line, owe their peculiarities and characteristics to the concomitant operation of the forces producing deformation and to oceanic currents.



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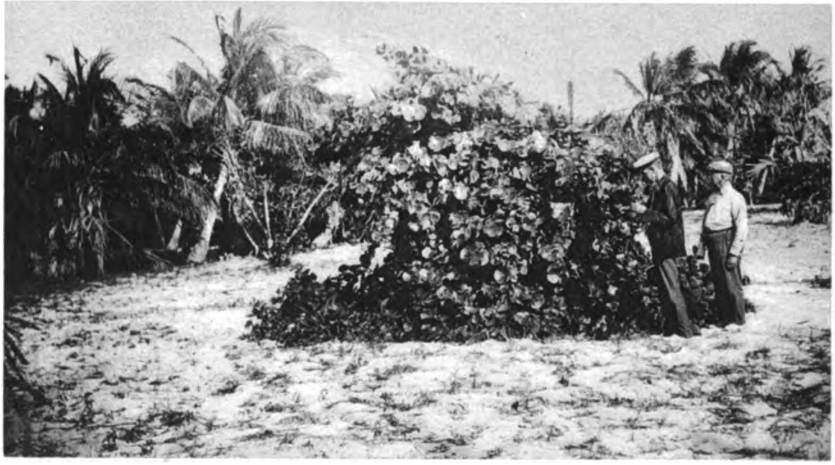

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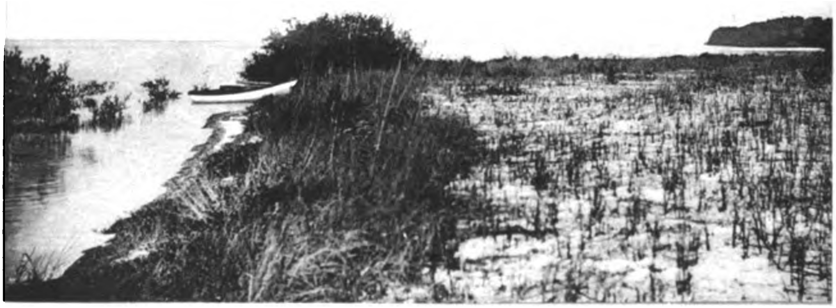
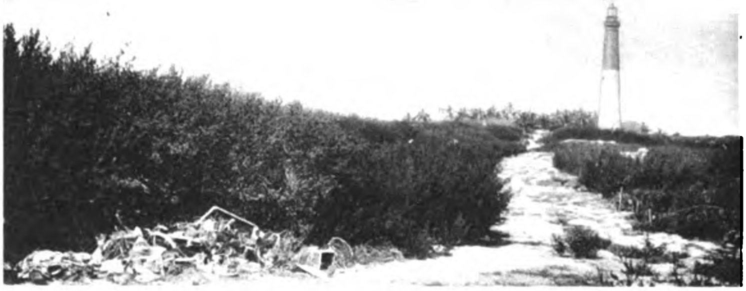


C.

A, Cape Florida, showing surface of siliceous sand and cocoanut palms.

B, Cape Florida, showing surface of siliceous sand and sea-grape.

C, The Marquesas, south side, beach ridge of calcareous sand in the foreground, mangroves in the distance.



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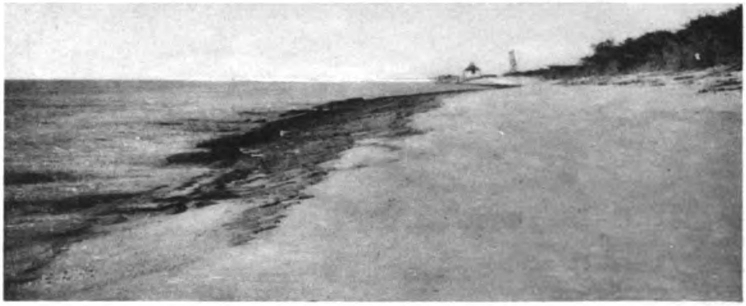

B.

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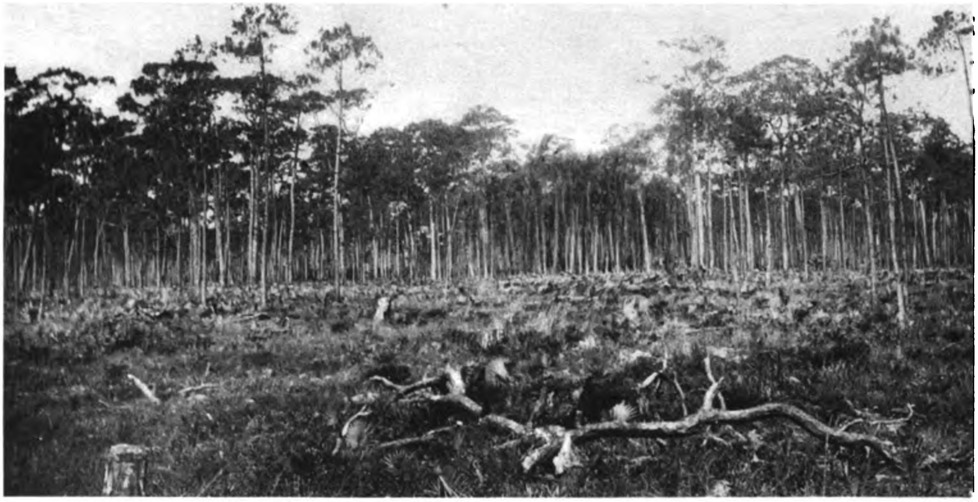
D.

A, Loggerhead Key, showing bay cedars and loose calcareous sand.

B, Loggerhead Key, western beach, northeast of lighthouse, showing passage of beach curve from indurated material along water's edge into that of loose material above it.

C, Edge of the Everglades, near Miami, showing saw-grass.

D, Edge of the Everglades, near Miami, showing a lily pad.



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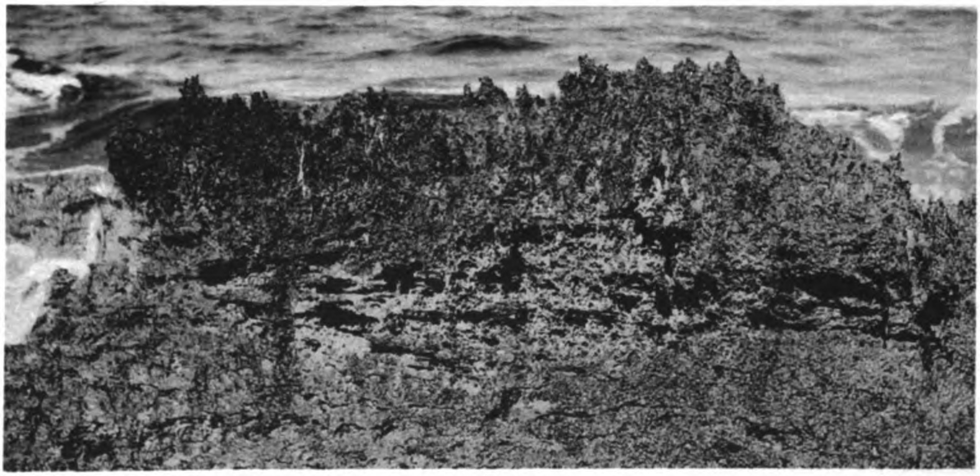

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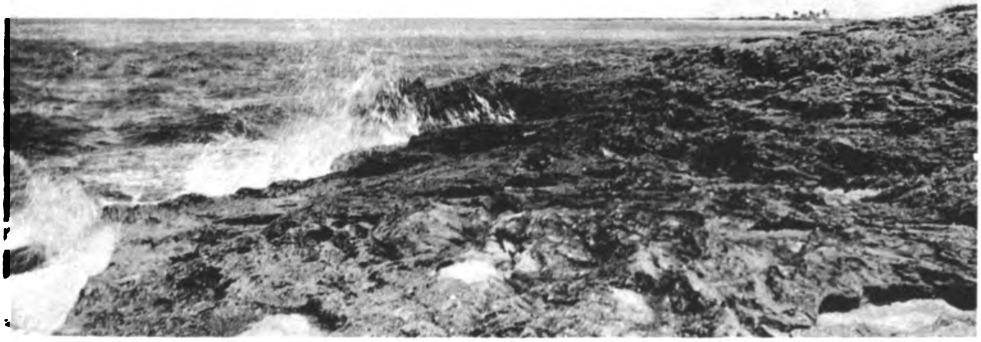
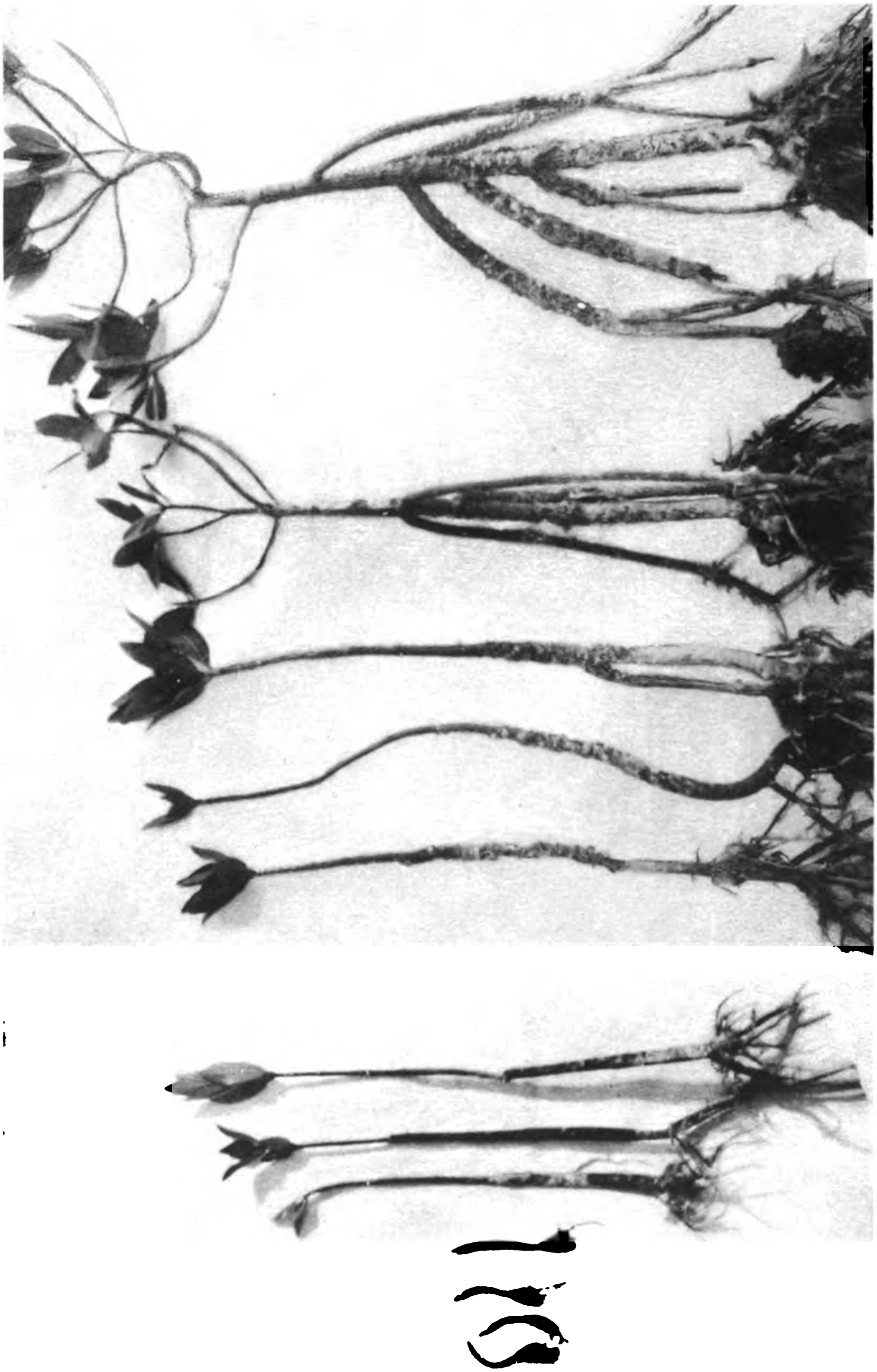
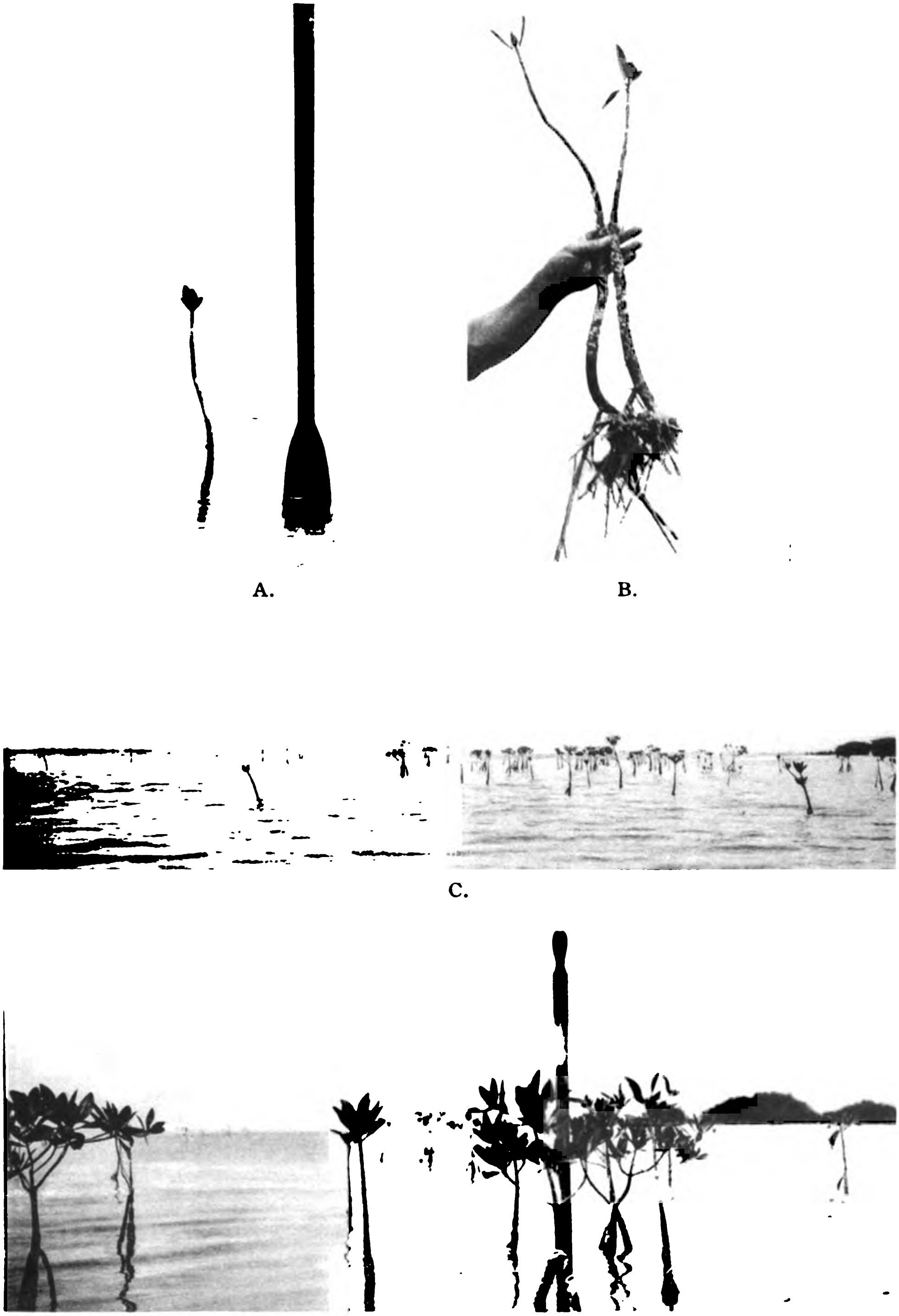


C.

A, Miami oolite, pine lands, outskirts of Miami.
B, Erosion by sea-spray, Picquet Rocks, Bahamas, western shore, distance 15 feet.
C, Erosion by sea-spray, Gun Key, Bahamas, western shore.



Young mangroves, showing stages of development from the pod. The four small figures represent pods plucked from the tree.



A.

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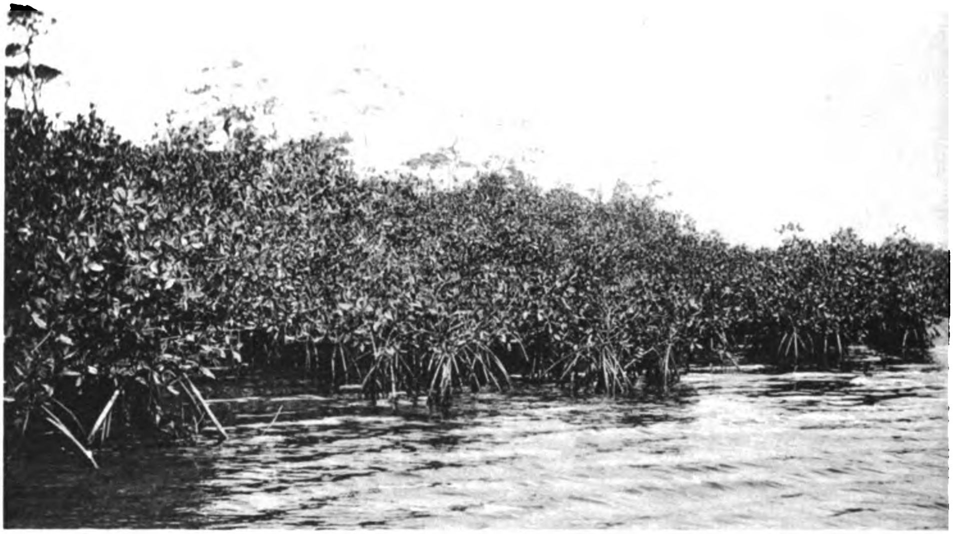
Young mangroves. A and B, shoal about 2 miles north of Pigeon Key, water about a foot deep. C and D, shoal upper end of Long Island, water about a foot deep.



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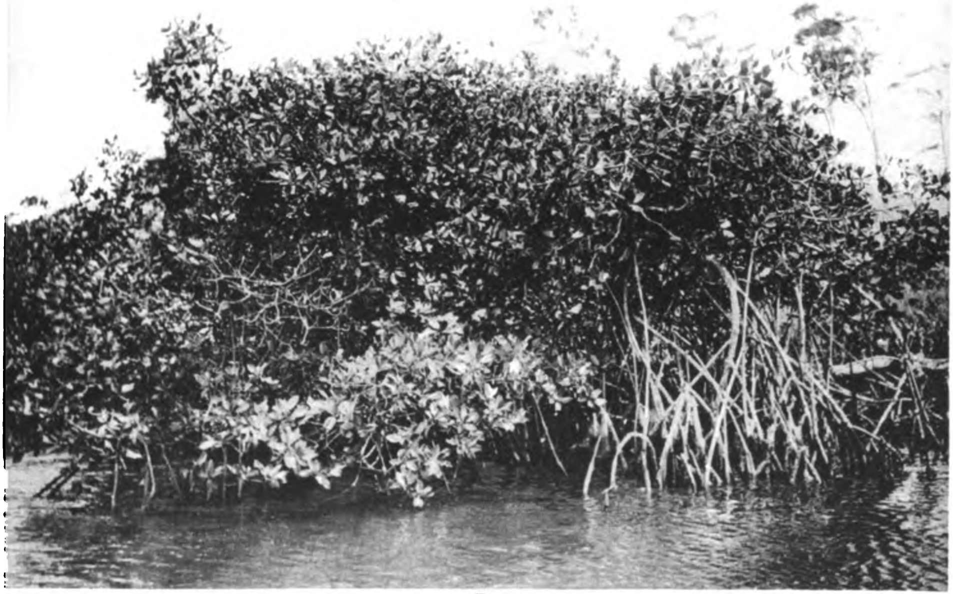

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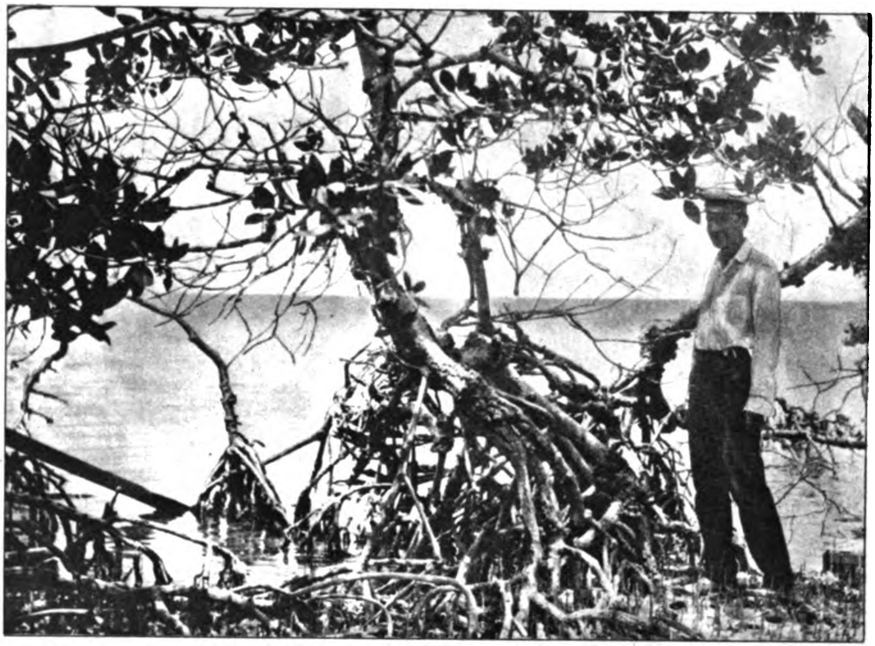
Mangroves, Miami River.



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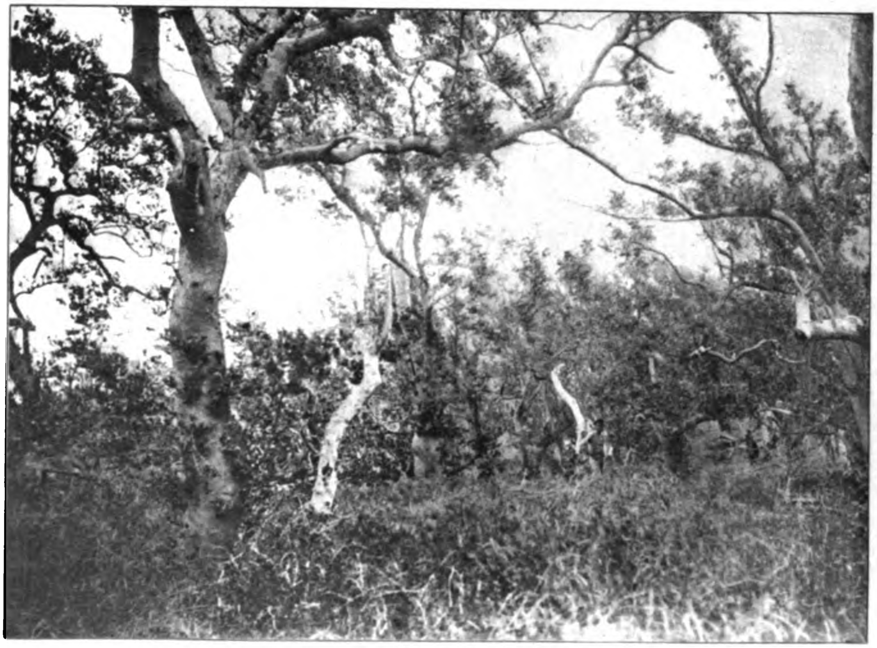
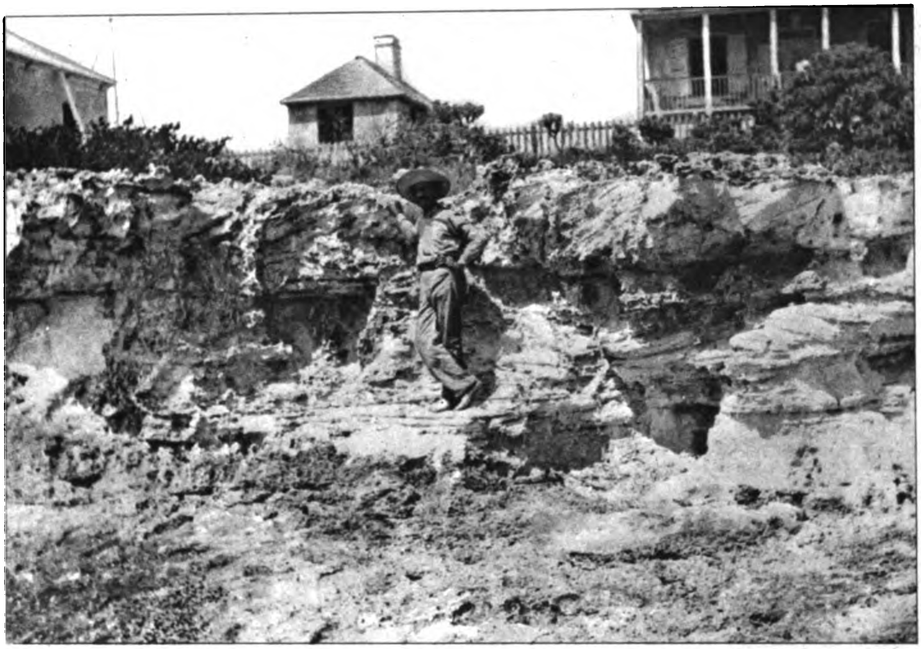


B.

A. Mangrove roots, Pigeon Key.

B. "Black Mangroves," Pigeon Key.



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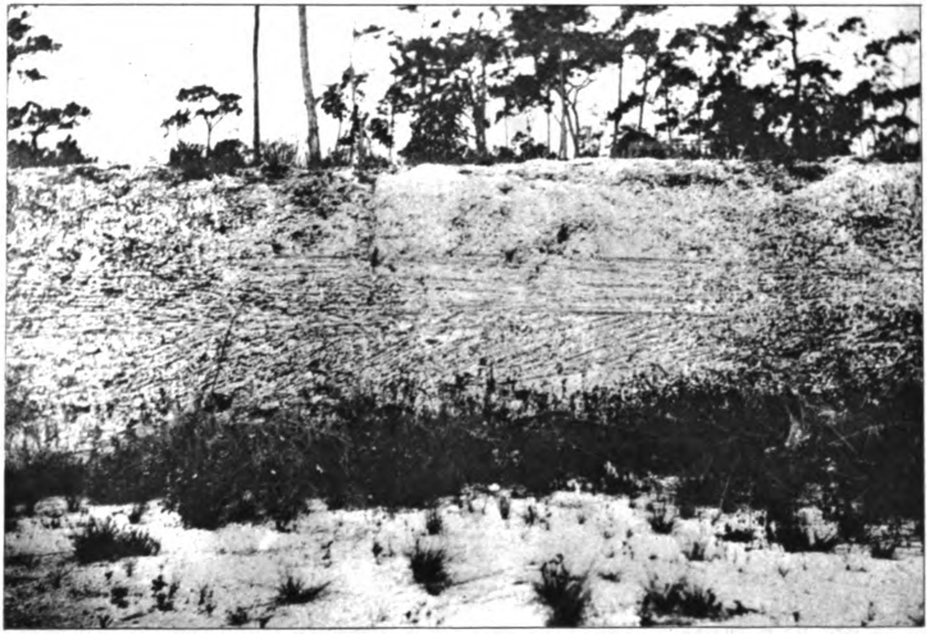
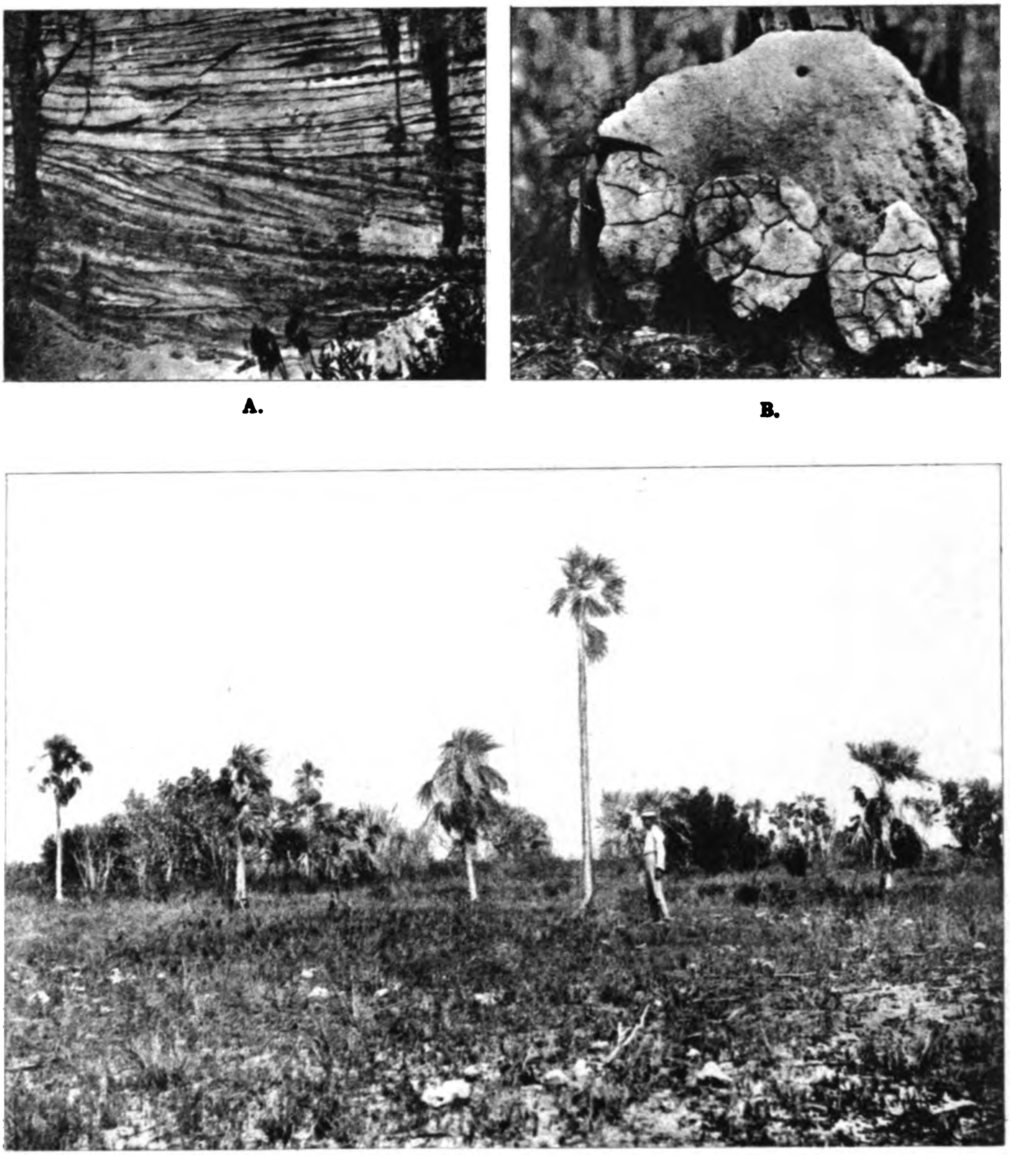


B.

A. Cross-bedded calcareous sandstone, probably æolian, western side of Gun Key, Bahamas.

B. Miami oolite exposure, Miami, showing cross-bedding.


A.

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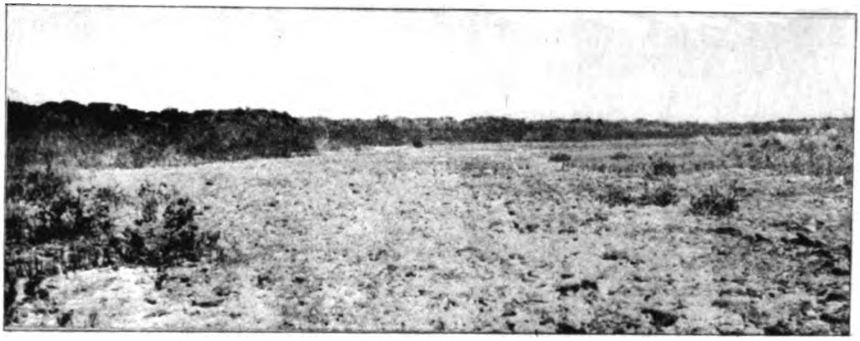
C.

A. Cross-bedding by water in an Eocene exposure, Central of Georgia Railway, two miles northeast of Andersonville, Georgia.

B. Mud cracks, surface of Key West oolite, Big Pine Key.

C. Surface of Key West oolite, Summerland Key.



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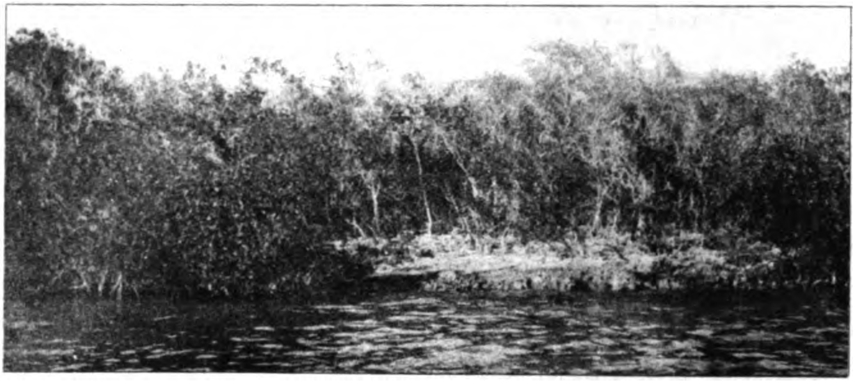

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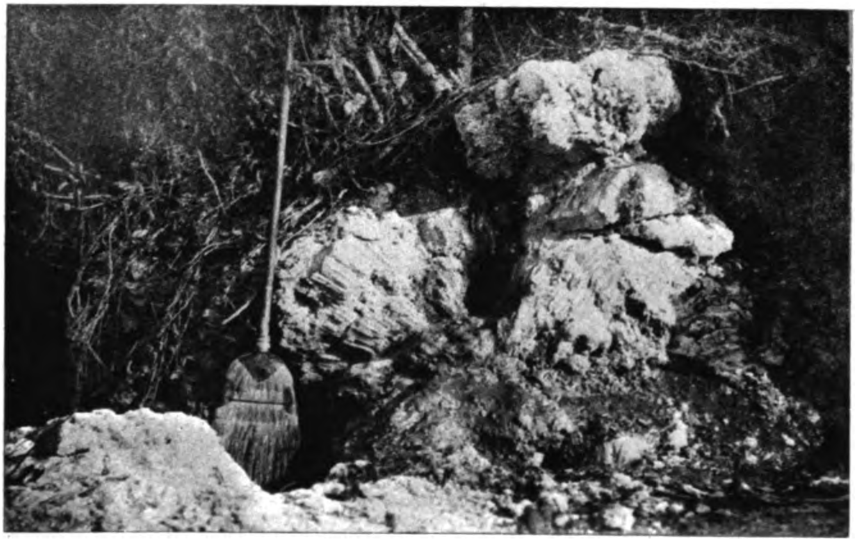

C.

A. Surface of Key West oolite, Boca Grande Key.

B. Key Largo limestone, southern end of Old Rhodes Key.

C. Coral head in Key Largo limestone, Key Vaca.

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